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Final Report

ALTERNATIVE AUTOMATED DATA PROCESSING SYSTEM CONCEPTS FOR SUPPORT OF THE FMF (1980-1990)

Volume III: ADPS Technology Estimate for the 1980's

By: L. S. PETERS, K. R. AUSICH, G. F. WALLACE, C. G. KERNS, E. B. SHAPIRO, and J. H. WILLETT

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This document is one volume of a five volume final report that describes the results of a study effort to identify alternative ADP concepts for the Fleet Marine Force (FMF) during the 1980s. The focus of the study was the administrative type of information processing associated with the management of manpower, operations, and logistics activities of the FMF rather than the tactical control activities. The goal of the study was to define alternative ADP concepts that could serve the FMF's needs in garrison, afloat, and within

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a combat area. A systematic analysis approach was employed that analyzed requirements, ADP technology, ADP system architectures, operational effectiveness, and system cost. The individual volumes of the final report are titled: Volume I: Study Overview and Results; Volume II: FMF Information Processing Requirements; Volume III: ADPS Technology Estimate for the 1980s; Volume IV: Description and Analysis of Alternative ADPS Concepts; Volume V: Cost Analysis for Alternative ADPS Concepts.

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Naval Warfare Research Center
Final Report

June 1977

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PREFACE

This volume is part of the final report of SRI Research Project No. 4950, entitled "Alternative Automated Data Processing System Concepts for Support of the FMF (1980-1990)."* SRI initiated this 20-month study in November 1975 for Headquarters, U.S. Marine Corps under Contract No. N00014-76-C-0582 from the Office of Naval Research. HQMC project management was initially provided by the Information Systems Support and Management Division, now a part of the Command, Control, Communications, and Computer Systems Division.

The study followed the approach described in the SRI Study Plan, "Alternative Automated Data System Concepts for Support of the FMF (1980-1990)," dated 1 January 1976--as approved and modified by CMC letter RDS/ISMS-11-pmb 5230/1 dated 26 Mar 76.

This is Volume III of the final report which consists of five volumes whose titles are:

Volume I : Study Overview and Results

Volume II : FMF Information Processing Requirements

Volume III: ADPS Technology Estimate for the 1980s

Volume IV : Description and Analysis of Alternative ADPS Concepts

Volume V : Cost Analysis for Alternative ADPS Concepts.

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*As defined by governing Marine Corps documents, an automated data processing system (ADPS) is an interacting assembly of procedures, processes, methods, personnel, communications, and automatic data processing equipment (ADPE) for performing a series of data processing operations--a combination of automatic data processing resources and automated data systems. An automated data system (ADS) is an assembly of procedures, processes, methods, routines, or techniques (including but not limited to computer programs) united by some form of regulated interaction to form an organized whole, specifically designed to make use of ADPE.

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Volume I describes the research objectives and provides an overview of the entire project, along with a comprehensive study bibliography. It also includes an Executive Summary.

Much of the material contained in these volumes was published previously in draft form during the course of the project as SRI Technical Notes. However, the material has been revised and reissued in the final report, which supersedes all the previously published interim and draft material.

I INTRODUCTION

This document reports the results of the SRI research to identify the automated data processing system (ADPS) technology that will be available to support alternative ADPS concepts for the FMF in the 1980's. The goal of this research was to provide a relatively complete and coordinated (though not exhaustive) summary of the technical aspects of future ADP as a reference point for proposing and evaluating ADPS alternatives for future FMF use. As such it complements SRI's identification of FMF information processing requirements (Volume II of this final report), and establishes the technical feasibility of meeting those requirements in the context of FMF operations.

The approach that SRI used in its technical survey of ADP capability was based on the separate review of the major component areas of ADP. Separate sections of the main body of this volume address these traditional areas of ADP concern. In order of their presentation, these areas are:

- Computer hardware technology
- Data base technology
- Software technology
- Nonautomated ADS procedures
- Telecommunications technology
- System architectures.

The purpose of each section is to review the technical status of the subject area; to provide a perspective of the technology in the context of issues that confront FMF use of ADP systems; and to provide projections concerning the applicability of emerging technology to FMF operations in the 1980's. Each section is based on the knowledge gained from inspection

of the current ADP literature, and by consultation with experts in these fields. No original research has been conducted; rather, SRI has attempted to interpret and meld together the results of more detailed research by other studies of this subject.

An appendix provides support and background concerning the interrelationship between telecommunications and ADPS. It establishes in detail the functional and practical considerations that govern the flow of information within an organization, and it relates these considerations specifically to the FMF context.

II COMPUTER HARDWARE TECHNOLOGY REVIEW

The purposes of this section are: (1) to provide an estimate of ADPE that will be available in the 1980s based on the present state of computer hardware technology and its near-term trends, and (2) to interpret that estimate for its probable impact on ADP system concepts for the FMF during the 1980's.

In reviewing computer technology, attention is given to those macro-characteristics that are most closely associated with "computer power," namely: attributes of the processor, the capacity and access rate of the memory units, rates of data transfer, and qualitative aspects of the input-output (I/O) devices. Physical characteristics of size, volume, weight, power consumption, and ruggedness of ADP equipment are also addressed where they appear to have an impact on selecting those alternatives that might best meet operational constraints.

Since management-oriented ADPS has been emphasized over real-time tactical command and control ADPS in this study, the technology review emphasizes general purpose ADPE closely associated with that which will be commercially available. The leading edge of technical developments will be identified where it adds perspective, but because of the short lead-time available for development prior to the early 1980s, low risk technology has greater significance.

A. Processor Technology

The central elements of ADP systems are the processors. A central processor unit contains the arithmetic-logical execution units, control units, and a data stream that goes to and from the addressable main memory. Separate data paths typically exist between the processor and the controllers of I/O devices or telecommunication interfaces.

Since a broad spectrum of ADP capability is required to provide for well-matched support of different levels of ADP activity within the FMF, a major aspect of processor technology is the existence of a spectrum of processor capability that extends from large general purpose computers to smaller minicomputers and microcomputers.[1] Broad characteristics of these computer classes are shown in Table 1.

Microprocessors are currently receiving significant attention in research and development for a variety of new, but primarily single function, applications. Minicomputers are increasingly being used for the general management applications that have previously been performed on the larger general purpose computers. The rationale for these trends is the rapid advance in semiconductor technology that has placed heretofore unrealizable levels of computing power in packages that are small enough to be dispersed to the working areas of their primary users. Low cost and more capable software contribute to this flexibility.[2]

Functionally, it is this distinction--throughput ("number crunching") orientation versus transaction orientation--that marks the boundary between the primarily fixed-site larger computer systems and the smaller minicomputers and microcomputers. Large ADP system applications will be dominated during the 1980's by extremely powerful multiprocessor computers that will provide for large throughputs as well as increased functionality, for example, multiple virtual memory architectures. Large single processor computers, having capabilities similar to those of current machines, will continue to exist, and their performance will be faster (through the use of parallel logic) and their cost lower. However, the basic computing power of this latter group will be matched by the computing power of a variety of minicomputers whose physical characteristics (size, weight) are much more amenable to FMF use.[3] In fact, an ADPS for the FMF in the 1980's may possess minicomputers that are functionally equivalent to the large general purpose computers currently serving the FMF.

The minicomputer is so-called because of its smaller scope relative to that of the large general purpose computers. In this class, a rapid

Table 1

CHARACTERISTICS AND EVOLUTION OF PROCESSOR TYPES

Processor Characteristics	1977	1985
Microcomputer		
Usage orientation	Device controller or single application computer	Stand-alone terminal perhaps with telecommunications ability
System software	Firmware oriented	Firmware oriented
Main memory capacity	4-8 kbytes	32-64 kbytes
Auxiliary storage capacity	300 kbytes	500 kbytes
Peripheral support	Rudimentary capability	Limited capacity
Processor Cost	$1-2k	$0.3-0.5k
Minicomputer		
Usage orientation	Dedicated processor or limited general purpose computer	Small user group utility with telecommunications ability
System software	Special purpose or general purpose limited in size and variety	Special purpose or general purpose limited in size and variety
Main memory capacity	32-256 kbytes	500-1000 kbytes
Auxiliary storage capacity	1-8 Mbytes	4-30 Mbytes
Peripheral support	Special purpose equipment and limited capacity I/O units	Special purpose equipment and limited capacity I/O units
Processor Cost	$10-20k	$10-25k
General Purpose Computer		
Usage orientation	Full service computer or host for multi-user systems	Full service computer or host for multi-user systems
System software	General purpose, full range of options	General purpose, full range of options
Main memory capacity	0.5-16 Mbytes	2-64 Mbytes
Auxiliary storage capacity	10-200 Mbytes	30-500 Mbytes
Peripheral support	Large capacity I/O units	Large capacity I/O units
Processor Cost	$150-2500k	$75-2000k

Note: Costs are in constant 1977 dollars.

Source: Reference 1 and review of current ADP periodicals.

increase in performance is taking place through the use of faster processors, microprogramming, and the development of parallel operations.[4] Minicomputers will continue to be configured in systems designed to serve specialized purposes (for example, communications processors) or small groups of users (for example, a work area). For these reasons, minicomputer configurations stress ease of use rather than throughput in a real-time environment. Yet the class is expanding so that the more capable future minicomputers will provide most of the same services that current larger computers do.

Finally, the microcomputer or, "computer on a chip," similar to today's microprocessor but with significantly more computer power, will serve individual applications, as well as be used as a device controller in large systems. Together, minicomputer and microcomputer technology are providing the basis for distributed "intelligence." They are the core for the existence and integration of intelligent or standalone terminals that promise to be the means by which information processing can be brought to the lower levels of the FMF organization. They are, in essence, the backbone for providing inexpensive, user-oriented, accessible computing power at various levels of a multi-level organization.

Just as important to the FMF as the promise of highly capable computer power in user-oriented packages is the promise of highly flexible ADP operating conditions. Minicomputers and intelligent terminals currently operate well in normal office environments. They typically require little in the way of special environmental support, and they can be simply moved and restarted. Operations and maintenance personnel requirements are slight compared to the traditional ADP staffs working in centralized service bureaus. Extrapolation of these capabilities to the 1980s strongly suggests that the ADP technology will effectively satisfy FMF operational requirements.[5]

B. Memory System Technology

Computer memory devices have memory access times that are orders of magnitude larger than the processor logic circuit delay times. Furthermore, the access times increase with increased storage capacity. It has

therefore become necessary to employ memory system architecture features that reduce speed mismatches between processor circuitry and memory devices. The alternative designs for memory-system architecture include: hierarchies of memory units having fast block-transfer capabilities; interleaving sets of fast-access memory which can fetch and transfer independently; and multiple memories that operate concurrently.[6]

The contemporary memory units are generally classified into the following four types;[1] they are presented sequentially, starting at the processor:

- Buffer memory--This unit is a relatively small capacity (up to 10^5 bits) but fast (less than a 100 ns cycle time) random-access memory
- Random-access memory (RAM)--This unit has a large storage capacity (typically 10^6 bits) and a relatively fast cycle time (0.5 to 1 μsec)
- Mass memory--Such units have a very large storage capacity (10^7 bits and above), but relatively slow access time; they include such types as: (a) an extended random-access memory that has a storage capacity up to 10^8 bits and a cycle time of 2 to 4 μsec; (b) block-addressable memories (BORAM) that have storage capacities of 10^7 to 10^8 bits and cycle times of 50 μsec; (c) rotating memories comprised of magnetic drums (10^7 to 10^8 bits, 10 ms access time), magnetic disks (10^8 to 10^9 bits, 100 ms access time), and magnetic tapes (10^8 to 10^{10} bits, 100 sec access time).
- Special-purpose memories--These are read-only memory (ROM), and programmable read-only memory (PROM) units that provide high-speed access and nondestructible readout for control applications (microprogram storage) as well as execution units (constants, tables). Based on semiconductor or electro-optical technology they are expected to develop extensively for use during the 1980s.

A summary of various types of memory technologies is shown in Table 2.

A memory hierarchy is, in effect, a sequence of buffer storages designed to match the high speed of the processor to the lower speed mass memory, and thus handle mismatches in I/O data streams. Other reasons for having storage hierarchies are for economy or operations, the need for large amounts of on-line information, and the increasing storage requirement of sophisticated computer programs. Since explicit

Table 2

CHARACTERISTICS OF MEMORY TECHNOLOGIES

Type	Volatile	Mechanical	Data Access	Size (Bits)	Access Times	Cost/Bit
TTLM RAM	Yes	No	Random word	10^3-5x10^5	60 ns	5¢
MOS RAM	Yes	No	Random word	$4x10^3-10^6$	300 ns	1.25¢
CCD	Yes	No	Random block	$2x10^5-2x10^8$	0.1 ms	0.03-0.05¢
Core	No	No	Random word	10^5-5x10^7	500 ns	0.7¢
Bubble Domain	No (NDRO)	No	Random block	$5x10^5-2x10^8$	0.5 ms	0.03-0.05¢
Floppy Disk	No (NDRO)	Yes	Serial block	$5x10^5-5x10^6$	100 ms	0.05¢
Cassette	No (NDRO)	Yes	Serial block	10^6-10^7	10 s	0.04¢
Head/Track Disk	No (NDRO)	Yes	Serial block	10^7-2x10^8	8 ms	0.08¢
Moving Head Disk	No (NDRO)	Yes	Serial block	$5x10^7-5x10^9$	50 ms	0.0025¢
Tape	No (NDRO)	Yes	Serial block	10^8-10^{10}	10 s	0.0001¢

Note: NDRO (Non-destructive read out).

Source: Reference 7.

management of storage hierarchy is very difficult for the programmer, advanced computers accommodate software that provides a "virtual memory" concept--an automatic sequencing of memory data transfers between the levels of the hierarchy to allow programming as if a very large main memory were always available.

Memory technology developments will affect all levels of the memory hierarchy. From the general ADP viewpoint, a most significant development will be the advances in electro-optical random-access memory which will store 10^8 to 10^{12} bits of data in pages accessible in 0.1 to 10 μsec and will read at a speed of 100 megabits/sec into a buffer memory or set of interleaved buffer memories. Holographic storage with laser reading/writing is the basis for this technique. More important to the FMF, however, will be advances in magnetic domain-wall motion technology, "bubble memories" and charge-coupled devices (CCD's). Such memory technologies can be arranged into shift-register configurations to provide nonrotating cyclic storage in place of the storage currently provided by mechanically actuated drums and disks. This will impact the FMF because the absence of mechanical components will increase the operational applicability of the memory devices, and because these technologies will be cost-competitive even for minicomputer systems. Finally, bubble memory is especially attractive because it is nonvolatile.

Few dramatic changes are anticipated for current storage devices. A steady improvement in performance, reliability, and reduction in cost is expected. Disk or diskette type storage systems will continue to be used in a variety of capacities. Improvement will come in bit-packing density (leading to higher transfer rates), track-packing density (reducing access time), and in head technology (leading to greater use of head-per-track disks and further reductions in access time). Table 3 shows the estimated capacity, performance, and cost of storage devices projected to be available in the 1977-1985 time frame.

One evolving aspect of current storage technologies is the improved capability for data transportability through such media as cassettes, diskettes, and floppy disks. The FMF operational requirement is such

Table 3

SUMMARY OF STORAGE MODULE PERFORMANCE/COSTS FORECASTS

Processor Characteristics	1977	1985
Microprocessor Auxiliary Storage		
Capacity	5 million bytes	5 million bytes
Medium	Small fixed disk	Bubble memory, CCD
Access time	10 milliseconds	10 microseconds
Cost	$2500-3500	$1500-2500
Minicomputer Auxiliary Storage		
Capacity	50 million bytes	50 million bytes
Medium	Small removable disk	Bubble memory
Access time	30 milliseconds	0.1 milliseconds
Cost	$15-20,000	$15-25,000
Uniprocessor Auxiliary Storage		
Capacity	200 million bytes	500 million bytes
Medium	Head/disk cartridge	Head/disk cartridge
Access time	25 milliseconds	20 milliseconds
Cost	$35-45,000	25-35,000
Multiprocessor Auxiliary Storage		
Capacity	2 billion bytes	5 billion bytes
Medium	Multiple disk unit	Multiple disks
Access time	25 milliseconds	20 milliseconds
Cost	$180-220,000	$90-130,000

Note: Costs are in constant 1976 dollars. Monthly rentals are typically 2.5% of purchase price.

Source: Reference 1 and review of current ADP periodicals.

that it is extremely attractive to have a means of transporting machine-readable data and applications programs by physical means as well as by electronic telecommunication. The trends in the technology of transportable media suggest that the near future will bring a doubling of storage density in this area with even larger increases following that. This means that such media will be smaller and have more capacity in the future, making them well suited to future FMF operational needs.

The cost of computer memory has decreased several orders of magnitude with the introduction of memory systems using bulk-material properties for storage rather than individual circuit elements. As the technology of these devices has advanced, their cost has further decreased at a very rapid rate. It appears that with the current rate of development in CCD's and bubble memories, a better and cheaper memory than the current magnetic disk and drum technology will be available for some applications by 1978. Table 4 shows a comparison of the characteristics of bubble memories and CCD storage technologies. For a transportable, highly mobile ADPS that could serve the FMF, the advantages to be gained from the reliability of nonrotating memory technology, especially from the nonvolatility of bubble memory over CCD's are significant.

C. Input/Output Devices

The most significant change in I/O devices is expected to occur in the capabilities that can be obtained in intelligent and/or interactive data terminals incorporating micro-computer systems. This change will bring a significant improvement in the use of such terminals for data handling.[8-10] Data entry and validation will be more effectively handled by procedures that are available and apparent to the user inputting the data. Furthermore, data entry can be improved through this technology to include "prompting" and "recipe selection" assistance to the user. Since such data entry is an area that currently accounts for 25% to 40% of ADP system costs, the projected performance improvements in computer terminals will permit a much more efficient and responsive ADPS.

Table 4

COMPARISON OF BUBBLE MEMORY AND CCD's FOR COMPUTER STORAGE

Bubble Memory Technology	CCD Memory Technology
Easy to manufacture	Easy to manufacture
Reliable, low cost (0.03-0.05 cents/bit)	Reliable, low cost (0.03-0.05 cents/bit)
Speeds of several hundred kHz (access time 10^{-2} to 10^{-3} seconds)	Speeds of several MHz (access time 10^{-3} to 10^{-4} seconds)
Non-volatile--holds stored information when power removed; information easily maintained	Volatile--requires standby power; needs refreshed continually to maintain data
Peripheral functions supplied externally (e.g., sensing and control circuitry)	Can readily incorporate sensing and control circuitry
High packing density (2.5×10^6 bits/in)	High packing density (10^6 bits/in)

Source: Reference 7.

A summary of the I/O devices that might have application in the future FMF ADPS includes:

- Hard-copy devices: Included are line and page printers, and graphical plotters.
- Interactive terminals: Included are all keyboard or graphic input devices (light pen, tablet) that are combined with a typewriter printing mechanism or electronic display device.[11]
- Data entry interfaces: Included are special font keyboards, voice devices, optical character recognition devices, card punches, and tape perforators.

Punched card and paper tape devices are electromechanical devices whose manufacturing technology has reached a high degree of maturity. Card readers have attained speeds of 2000 cards per minute, and cards can be punched at the rate of 500 cards per minute. No large improvements in these speeds are projected, although reliability should be improved. Computer card processing is not seen as applicable to the future FMF ADPS, however.

Nonimpact printing techniques (for example, ink-jet, thermal, electrostatic, xerographic, and electro-optical) offer increased speed, and decreased weight, volume, and cost for hard copy printing. Their reliability is improved over that of impact printers because of less mechanical actions, but they may require special paper.

Optical character recognition (OCR) devices input data directly from hard-copy documents or from microfilm. Current equipment achieves character-input rates as high as 2400 characters per second and processes documents at the rate of 1500 to 2000 per minute, depending on the document type. Current OCR problems include lack of flexibility in handling a variety of character fonts on a given document and relatively high reject rates because of inability to resolve fuzzy characters. In the 1980's these shortcomings may be rectified, and reliable, versatile, low-cost OCR's should be available. However, it is expected that these devices will continue to require a temperature controlled dust-free environment for efficient operation.

Current keyboards are electromechanical in nature and have relatively low reliability. Solid state keyboards without moving parts are undergoing development and becoming available; these promise improved reliability. It is projected that solid state keyboards will be used in the 1980's. They will reduce maintenance and be relatively insensitive to the adverse environments associated with FMF operations.

Prior to the microprocessor era, displays in terminal consoles were almost exclusively cathode-ray tube (CRT) devices that required access to a large computer for updating at rates greater than 30 times a second. Associated with the terminal was a controller that contained the buffer memory for refreshing the display and executing the instructions for display generation. At the present state of technology, display terminals with embedded microprocessors have stand-alone capability for transaction processing, alphanumeric display, text editing, and graphical display.

Displays under development and to a limited extent commercially available will provide more sophisticated capabilities for curve drawing, multiple color, and halftones. In the future, greater use of microprocessors and associated circuitry will provide improved display versatility, and resolution at reduced costs.

In the early 1980's CRT displays are expected to be strongly challenged by some form of flat display surfaces employing solid state technologies; such surfaces may include plasma displays, liquid-crystal displays, and ferro-electric displays. These technologies, which are now in the laboratory and in limited production, offer the long awaited breakthrough in flat-panel television and data terminal displays. They promise to be smaller, weigh less, and be more reliable than CRT displays.

D. Implications of Hardware Technology

The preceding subsections have briefly reviewed the present state of computer hardware technology, the near-term advances that are emerging, and the directions that it may be expected to follow in the future. It is most important that the implications of these advances be made

concerning "What do these technical capabilities have to offer for ADPS in the FMF during the 1980's?" In addressing this question, the following issues arise:

- What hardware capability is available to meet a diverse range of information system requirements at various levels within the FMF?
- What can be inferred about the deployment of future hardware in terms of weight, volume, and environmental conditioning requirements?
- What is the potential for modularity of ADS service based on the available hardware options?
- What hardware features are available or becoming available that will relieve telecommunications burdens?
- What are the forecasts for improved compatibility/interoperability with automated equipment within the Marine Corps, other Services, and WWMCCS?
- How will advanced technology affect the man/machine interface?

Equally significant to the FMF ADPS are the environmental conditions under which computer hardware will be required to operate. Such conditions include those associated with:

- Extreme temperature variations
- Humidity, or corrosive vapors (such as salt spray and others)
- Vibration and shock associated with equipment transport, and the consequences of being located within the AOA under combat conditions
- Electromagnetic or nuclear radiation
- Dust and other flying particles
- Unstable power sources.

Even in the presence of these severe environmental conditions, the requirements of the FMF demand that ADP hardware perform effectively. The main requirement of FMF ADPE is that it be reliable.

Furthermore, new or advanced computer technology for the FMF must be directed at simplifying the tasks/missions of the user instead of complicating them. Factors that must be considered in the selection of appropriate concepts include these:

- The FMF ADPS must be nearly 100% available during the normal transitions from garrison to afloat to combat ashore, and flexible enough to adapt to typical changes in operations (in terms of type and intensity).
- The FMF ADPS must be highly reliable for the typical deployment of from 1 to 6 months and not require highly trained personnel for its use or repair.
- The FMF ADPS must be mobile and transportable in all environments. This will require consideration be given to the weight, cube, and support requirements as these factors affect MAGTF operations.

SRI has conducted an initial examination of the various ADP equipment physical characteristics that will affect mobility, transportability, and support requirements. It appears from these data that the FMF ADPS of the 1980's should consist of several modules that are small, lightweight, and can be operated with self-contained power or with generators that are part of the normal MAGTF equipment.

Since the FMF organization cannot easily accommodate changes in the organizational structure or an increase in the skill level of ADPS personnel to support its ADP system, the required type of ADP system must provide "user transparency." Great advances in user transparency are expected to be feasible with existing and projected technology by simply introducing the appropriate instruction set (in the form of a ROM) and the initialization data base in the form of a diskette, disk, tape, or some other type of input device.

The technology to develop such a FMF ADPS exists now, and it will be undergoing refinements principally in the areas of reduced costs, increased reliability, improved ruggedness and decreased maintenance. In selecting an FMF ADPS for use in the 1980s it is essential that the introduction of ADPE does not increase the present burden of software preparation, maintenance, and transfer to other systems. The selected hardware should also alleviate software problems by increasing the "programming transparency" of the hardware, thereby removing from the programmer/user with concerns about the architectural configuration of the computer system with which they are working.

The hardware technology that is currently available or in an advanced state of development offers modular capacity wherein the "computer power" can be matched to the job to be accomplished. For example, it is reasonable to consider equipment having technological equivalence to the "point-of-sale" systems that are in commercial use (where the equipment operates in a netted arrangement with a central computer, but it can also operate in stand-alone fashion without any distinguishable difference to the user).

At different echelons within the FMF, the requirements differ primarily in the size of the data base that is consistently accessed, the size of the programs used, and the urgency with which processed information is required. It is technically feasible to provide hardware that is tailored to serve the differing needs of the echelons or in response to wide variations in activity levels such as is common experience during preparation for a MAGTF deployment.

Present technology development is producing equipment having increased "computer power" and while at the same time decreased size, volume, and weight. It is presently possible to procure off-the-shelf an intelligent terminal with stand-alone microcomputer capability in a package that weighs less than 30 pounds. Additional memory can be added in the form of a cassette recorder as a package (completely compatible with a spectrum of computers, the size of a voice tape recording, and weighing less than 10 pounds). The recorder can record and play back at 120 characters/second, a rate compatible with a man/machine interactive system. If hard copy output is required, a matrix printer capable of producing 125 lines per minute is available. Such a printer weighs less than 20 pounds and is approximately the size of a portable electric typewriter.

In consideration of advanced technologies that offer substantial advantages to Marine Corps applications, solid state keyboards, nonrotating and nonvolatile memories, and nonimpact printers lead the way. All of these technologies offer substantial improvements in reliability

and availability of computer systems in typical deployed MAGTF environments either afloat or ashore.

The developing technology is emphasizing modularity of design, where the computer device can be specifically tailored to the needs of the organizational element that it accompanies. Processors can be purchased having the basic "computer power" required and can be augmented with memory or peripherals or be interconnected to provide gradations in capability as needed to satisfy the real requirements and/or grow with the natural evolution in automated applications.

The developments in solid state devices are currently offering data modems on a chip that can be directly incorporated into all computers including those associated with intelligent terminals. The development of these devices has resulted in an order of magnitude reduction in costs while providing coupling for available communications. These developments have resulted in terminals that can directly communicate via existing communications media. These developments will substantially reduce the cost and compatibility problems of equipment that are to be introduced into the FMF, and make effective integration of them with the existing and future communications systems under LFICS much easier.

With the availability of read-only memory devices, and programmable read-only memory devices it will be possible to insure direct control of the programs being used. Additionally, these devices provide decreased memory cycle time and greater integrity against accidental or intentional destruction.

In summary there appear to be no major technical obstacles to the introduction of powerful and effective automated capability throughout the FMF. The functional capability is available with current technology, given some size and weight constraints. Near-future technology seems well capable of meeting all functional and operational requirements.

III REVIEW OF DATA BASE TECHNOLOGY

A. The Impetus to Data Base System Development

Data is an important, durable resource rather than a commodity for one-time use and disposal. Experience has shown that once data is in machine processible form it is very likely to be used again at some later time, and it is frequently wanted by different users with new purposes and different computer programs. If existing data cannot be shared, then the penalty is duplication of the data by multiple users.[12]

When each individual programmer is in complete, arbitrary control of his own data, the conditions for regarding data as an organizational resource do not prevail. The smallest differences in content, organization, or format of data can make it unsuitable for another use without extensive reprogramming and reprocessing. Poor documentation and storage practices compound the problem--making otherwise good data an unknown quantity for another use at a later time.

The issue of data management is particularly significant since 40% to 60% of a programmer's code has traditionally been devoted to the verification, storage, retrieval, and maintenance of data.[13] In an environment where data is managed centrally for the purpose of sharing it, a large portion of this labor can be performed centrally once and for all and thus shifted from the individual programmer.

Two factors have been the major impetus to the development of data base systems:[14] The advantages and economies of sharing data among users, both simultaneously and over a period of time, and of centralized management of data to be shared.

1. The Character of a Data Base System

Although most popular discussion of data base systems focuses on data base management systems (DBMS), a full-blown data base system

(DBS) is actually a much more comprehensive entity of which the DBMS is but a major component part.[15] In order to embrace all important considerations in the creation and use of a DBS one should regard the system as consisting of the following nine components:

- Source data
- Stored data base
- Data dictionary/directory package
- DBMS
- Data-base administrator
- Data model (or schema)
- Various data submodels (or subschemas)
- User community
- Set of user profiles.

The nature of several of these components is self-explanatory, but others merit definition. The data dictionary/directory is a set of procedures and automated aids used for the definition, organization, and documentation of data.[16] The character of the data dictionary/directory and its relationship to the data base and the DBMS can vary considerably from system to system. In its simplest form it may be essentially a systematic and complete notebook of data definitions and descriptions. More highly developed instances may include automated directories that serve as an integral part of the DBMS.

The DBMS consists of the computer programs and the language constructs required for the creation, management, and use of the stored data base. Entry of new data into the data base, reorganization of data base files, and inquiries of data base files are examples of operations performed by the DBMS.

The data base administrator is a person or group responsible for preserving and enhancing the ability of the data base to serve the needs of its entire user community. The administrator's concern may be focused quite narrowly upon the data base per se, or more broadly on other aspects such as DBMS development as well. He enforces practices

that preserve data integrity, data security, and ease and efficiency of user access.

The data model reflects the logical (as distinguished from physical) organization of the data base. It is the logical view that the complete data base presents to the user community. The entities, attributes, and relationships embodied by the data base are inherent in the model.

The data submodels are logical data base views that are specifically tailored to the needs or access privileges of individual users or subgroups of users.

2. <u>Functions of the Data Base System</u>

A data base system exists to support four major functions. These are:

- Data definition
- Data query (or data access)
- Data manipulation
- Data control.

Data definition is an activity that specifies the format, content, and relationships of data to be entered into the stored data base. Data definition is performed by, or under authority of, the data base administrator.

Data query is the process by which information inherent in the content or structure of the data base is retrieved by users to answer specific needs. Data query can range from simple requests for items or sequences of stored data to very complex retrievals framed in terms of logical conditions that must be satisfied by the attributes of the entities described in the data base.

Data manipulation brings to bear the calculational power of the computer on the data of the data base. The generation of new data base files from existing files is a major action. Sorting retrieved information or the generation of data statistics are other common activities.

Data control embraces two major concerns: the maintenance and preservation of data quality, and the provision of data security. Data quality can be impaired by errors in input data, by erroneous updates to existing data, by program bugs in DBMS programs, by failures of hardware devices such as memory units, by improper computer operator procedures, and so on. Data security is impaired when data can be accessed or tampered with by users not entitled to do so. The need for data control is a prime reason for the existence of the data base administrator and of various automated control features built into the DBMS (and even the computer hardware) as well.

B. Data Base Management Systems

For automated data management, the major link between the functional responsibilities of the DBMS and the computer system that supports it resides in the DBMS. It is important, therefore, to identify physical attributes of the DBMS. First, any DBMS having fairly general features and functions will entail a significant amount of software. Second, a substantial amount of computer activity will be devoted to the execution of this software, and significant space in computer memory will be occupied by the DBMS routines. In most systems the DBMS software is designed to rely on and make full use of the operating system software of the host computer system, so that updates or changes in the operating system will have definite effects on the DBMS.

The presence of a DBMS on a computing system will have implications for the hardware configuration as well. The accommodation of a large stored data base requires large amounts of memory, and perhaps new and different types of auxiliary memory devices. Depending on the type of user access supported, the DBMS may require the addition of the appropriate inquiry and display terminals to the hardware of the system. Not to be overlooked is the possible need to augment the basic computing capacity of the system to support the increased processing load attributable to data base activity.

The relationship of the DBMS to the programming languages of the computing system is also of interest. Some DBMS offer and support independent, high level query languages to be used for making inquiries and retrievals from the data base. Some DBMS depend upon language constructs that are embedded or intermixed with the standard programming languages of the computing system, such as COBOL. Other DBMS offer both modes of user access. Thus, the presence of a DBMS may exert strong influence on the regular programming languages and language compilers of the system. Compilers may have to be modified and mated to the DBMS, for example.

1. Some Current Systems

There are numerous successful data base management packages available on the commercial market today; however, a small number of these, perhaps half a dozen, tend to dominate the scene.[17] These are all of either the so-called network or the network hierarchical type. Several have been strongly influenced by the DBMS specifications developed by the Data Base Task Group (DBTG) of the CODASYL organization. CODASYL (Conference on Data Systems Languages) is the group under whose aegis the specifications of the COBOL programming language were formalized in the late 1950's. In the late 1960's CODASYL precipitated work on DBMS, and a definitive report was issued by the CODASYL DBTG in 1971. The particular focus of DBTG was to specify data base management facilities suitable to be invoked by COBOL programs, but the influence of the work has been much wider.

For all the network-type DBMS, the logical structure of the data base is framed in terms of entities, the attributes of entities, and relationships between entities. An alternative data base organization called the relational data base is receiving much research and development attention at the present time. This is based on the mathematical theory of relations and can be proved to have many desirable characteristics that resolve some of the common difficulties of data bases. However, it will probably be some years before fully developed

relational data base systems capable of processing large data bases efficiently are implemented.

In Table 5, the characteristics of some of the most common current DBMS are tabulated. One should bear in mind that the DBMS software package purchased or leased from a vendor is but one of the components of the overall DBS characterized previously in these pages. Other components such as the source data and the data base administrator's organization, for example, must be provided by the user organization.

2. Current Experience with DBS

Over the past few years, many organizations have used one of the commercially available DBS's to accrue considerable first-hand experience. Many of the users are business corporations that have brought DBMS into major phases of their day-to-day operations. Their experiences, though somewhat mixed depending upon the type of problems addressed and the type of systems installed, have generally been positive. In respect to such considerations as the training required for users, the reliability of the systems, the effect of the DBS on the organization's computing operations, controllability of data as a resource, convenience, and overall cost, the systems have measured up well. In some cases, the adoption of a DBS has extricated an organization from an unworkable situation or permitted an organization to expand its activities into new areas not feasible without the DBS.

Although they are bringing overall benefits to many users, DBSs are still in an experimental and developmental phase. While nominally addressing a common set of needs, the available systems are quite diverse. This diversity appears in user languages, logical organizations of the data bases, physical organization of the data, and implementations of the DBMS routines. The active and generally satisfactory use of these diverse systems bodes well for future developments in the DBS area. The experience gained by users and designers alike will probably point the way to fruitful directions for the future.

Table 5

CHARACTERISTICS OF CURRENT DBMS

System Name	Supplier	Year of Intro.	Number of Users	Computers	Operating Systems	Pricing	Comments
IDMS	Cullinane Corp.	1973	65	IBM 360/370; Univac Series 70; DEC PDP/11-40 and above	IBM DOS, OS, VS; Univac TDOS, VMOS; DEC RSX	One-year license, $40,000	IDMS is designed to conform to the CODASYL Data Base Task Group's language specifications and so provides the requisite types of definition and control languages as well as the DBMS routines themselves. It also includes a data dictionary system.
TOTAL	Cincom Systems, Inc	1969	750	IBM 360/370 and System 3; Univac Series 70 and 9400/9700; CDC Cyber Series Honeywell Series 200/2000	IBM, DOS, DOS/VS, OS, OS/VS; Univac TDOS, DOS; CDC Cyber; NCR; Honeywell Mod 1 (MSR), Mod 2, OS/2000	Purchase, $26,500 to $28,500; Monthly rental, $750 to $950	TOTAL provides facilities for generation and use of a complete data base with comparatively general features. TOTAL is a host language system as distinguished from an independent query language system; it supports access from programs written in three different host languages, namely COBOL, PL/1, and FORTRAN.
SYSTEM 2000	MRI Systems Corp.	1971	300	IBM 360/370; Univac 1100; CDC 6000 and Cyber 70	IBM OS/VS: Univac EXEC 8; CDC DRONOS, SCOPE, and NOS	Paid up lease, $30,000; Monthly rental/lease from $1,195 to $2,665	SYSTEM 2000 is a full-scale generalized DBMS with interface capabilities for COBOL and other general-purpose languages in addition to a high level query language. The system is suited for fully integrated data bases as well as more limited files and data sets.
IMS	IBM Corporation	-	-	IBM 360/370 Siemens 4004	IBM OS, DOS, OS/VS, DOS/VS	Monthly license from $300 to $935 per month	IMS provides the facilities for generating and accessing a data base with automatic cross-referencing among data records. IMS can be had in versions that permit either batch or on-line operation. Depending upon the particular version used access is achieved through data language commands imbedded in program sequences written in a host programming language and also through one or more query languages used in either batch or interactive mode.
ADABAS	Software ag of North America, Inc.	1972	100	IBM 360/370; Siemens 4004	IBM OS, DOS, VS; Siemens PPS, BS1000	Purchase from $80,000 to $120,000 Lease available	The Adaptable Data Base System (ADABAS) is a data base management system for data base generation and access. It uses high-efficiency data management techniques and provides a generalized file-coupling capability. ADABAS operates primarily as a host language system, but an independent ad hoc query language is also provided. Report generation capabilities are available.

Table 5 (Concluded)

System Name	Supplier	Year of Intro.	Number of Users	Computers	Operating Systems	Pricing	Comments
MARK IV	Informatics, Inc.	1968	850	IBM 360/370 Univac Series 70 and 9400/9480; Siemens 4004	IBM OS, DOS, VS; Univac DOS, TDOS, OS/4; Siemens PBS	Purchase from about $10,600 to $37,000; Lease plans available	MARK IV is an advanced general-purpose file management system designed to reduce programming time for processing data files. MARK IV generates programs to perform user-specified functions from precoded routines in the MARK IV library. The user specifies the logical organization of his files and the data. He also may specify file update routines, file creation routines, and selection routines. These can become part of the library for use as future building blocks. Information requests are against files are made by filling out a tabular form. Extensive report generation facilities are included. On-line inquiry is not supported. MARK IV exhibits some data base management features since the system provides multiple logical views of records and files but the physical data exists only once.

Source: Reference 17.

C. Directions and Trends

Some DBS trends are quite apparent, and it is possible to predict some prospects for data base management in the 1980's. One definite trend is toward a high degree of functional equivalence between the existing major DBSs. The diversity between the current systems (pointed out above) extends to the functions that these systems can perform for a user. That is, there are functions performed by TOTAL that are not natural to SYSTEM 2000, and that are not directly supported by IMS, and so on. However, each of these systems represents a sufficiently large development investment and has a sufficiently large user base to give their suppliers considerable incentive to extend and improve the systems so as to lengthen their lives and broaden their user appeal.

The result is that although there are fundamental differences in design, implementation, and performance, there is a growing commonality in the types of functions these DBS can be made to perform for a user. Thus, by 1980 there will be few functions available to the user of one system that the user of another system cannot accomplish by one means or another. Some of the functional features that will be common to most major systems are the following:

- Support of full network data structures
- Random, sequential, and inverted data base access
- Data compression if desired
- Password security protection at the file, record, and field levels
- Lockout features for protection against concurrent update of records by multiple users
- Automatic backup and restart facilities on program failure
- Optimal pre-compilers for major programming languages
- Facilities for use in multiprogramming/multiprocessing environments.

With a high degree of functional equivalence among systems, choices between systems will tend to be made on the basis of other issues.

Another trend has to do with the underlying philosophy of the data base systems. Most of today's major systems are of the network or hierarchical network type. These terms refer to the basic structure of the logical relationships between the entities of the data base. The network approach to data base organization has received a great deal of research attention and has been the source of much user experience over the past 15 years; therefore, it currently dominates the commercial scene. The contrasting relational approach to data base organization is receiving much current research and development attention. Relational data bases, because of many desirable properties they can be shown to possess, are almost certain to develop into strong contenders in the data base management field within a few years. However, because of the large developmental efforts that will be required for them on several fronts--theory, software systems, memory technology--it seems doubtful that relational systems will be major contenders with proven track records much before the mid-1980s.

In recent months, the concept of the distributed data base has received much attention in the computing literature.[18-19] The essence of this concept is that portions of the data base physically reside at different locations and in fact are managed by various processors, but a user can access any data from his own location without regard to where in the system the data may actually reside. The notion of the distributed data base is intertwined with problems of distributed processing and telecommunications. In all of these areas, there are numerous outstanding questions of system organization and system control. Because of the current early state of development of distributed data base and distributed processing technology, the prospects for the creation of any large truly distributed data base system in the FMF operating environments in the early and mid-1980s do not appear attractive.

For several years, the pace of developments in computing hardware technology has been remarkable. The potential impact of new hardware on future DBM systems is of great interest. One of the main areas of interest is secondary computer storage. New mass storage devices offering greatly increased storage capacity, faster access times, and decreased costs per

bit are already appearing on the scene, with more to follow in the next 3 or 4 years.

The prospects are that both current and developing DBSs will be able to exploit these advances as they arise. Two technical reasons underly this fact. One is that DBMS are generally designed so as to make the logical organization of the data base as independent as possible of the actual physical storage of data. This means that significant changes--including the introduction of new memory devices--can be made in the physical storage without forcing serious changes in the user's view of the data base.

The second reason is that DBMS generally depend upon the standard operating system of their host computers to control the physical data access methods employed by the DBMS. This means that as operating systems are adapted to the introduction of the new memory devices, the new devices will become available to the DBMS. In respect to hardware advances in areas other than memory, the same thing will generally be true. As the computer operating systems are adapted to new hardware, the new hardware features will tend to become available to benefit the DBS.

D. Issues Affecting DBS

There are several issues that the prospective DBS user should be aware of before he commits his organization to a specific DBS. In most cases, clear trends are not yet apparent, and hence little can be said about how the issues will eventually be resolved.

One issue is standardization. In any area of data processing where similar types of user services are furnished to a large user community by a number of diverse systems, pressures for standardization of the user interface arise. Reasons of efficiency, user convenience, transferability of knowledge, and transferability of programs and procedures argue for standardization. The equally attractive advantage of preserving flexibility to develop diverse and perhaps better systems would seem to argue against it. The tortuous history of the standardization

of general-purpose programming languages such as COBOL and FORTRAN provides a well-known prototype.

One fact is generally accepted: before there exist viable and attractive candidates for standardization, the effort to standardize is premature. This is probably the situation of DBMS today.[20] No one system or data base philosophy is as yet a convincing candidate for standardization. Standardization of DBS will continue to be an important issue and perhaps may be achieved five or ten years hence. In the meantime potential users must be prepared to cope with lack of standards and with some uncertainty as to the direction that standardization may take.

Another issue affecting the DBS is that of generality versus efficiency. A system that is too general, that is, one that provides the user with a wide selection of services and options, will bring with it a high degree of system overhead. This overhead may be felt in terms of high cost per operation, slow response times, high system maintenance costs, or any combination of these and other negative factors. On the other hand, a system that is not sufficiently general, albeit efficient, can be unsatisfactory and frustrating to any but the narrowest user community. Although the issue will always remain to some degree, the prospects for advances in hardware, software, and system architecture give some promise that DBMS with considerable generality as well as with acceptable efficiency will soon be the norm.

The issue of the type of user language interface provided by a DBS is of considerable importance. Some systems provide access to data only through language constructs imbedded (intermixed) in programs written in a general-purpose programming language such as FORTRAN, COBOL, or PL/1. This means that individual users must either be programmers, or else they must transmit their requests to programmers who deal with the system. Other systems offer a high level query language that can be used by nonprogramming users to make direct information requests of the data base. Some systems offer both facilities. The nature of these access facilities is one of the prime determinants of the suitability of a DBS to a user's environment.[21]

Another issue concerns the type and degree of data protection provided by a DBS. Data protection embraces both the protection of data quality and the protection of data security. Data quality can be impaired by errors at input time, by deterioration during storage, by improper updates, erroneous program sequences, and so on. Data security is threatened when unauthorized users or other persons accidentally or intentionally gain access to data to which they are not authorized. Neither data protection nor data security is easy to achieve, and effective approaches are not well understood nor agreed upon; yet protection may be vital in a given operational context. The prospective DBS user should be well aware of this issue vis-a-vis his particular requirements.

A final issue is the question of just how integrated the data base management of an organization can and should be. One of the original motivating ideas behind the development of a DBS was that of totally integrating the data base management for an entire organization, such as an entire industrial corporation. Under this concept the sales data, personnel data, the financial data, the manufacturing data, and so on, would all be handled within a unified system. In actual fact, the instances where this has been accomplished for a large organization are the exceptions rather than the rule.

In many cases, various arms of the organization have used large, but nevertheless separate, data bases under different DBSs. For example, the manufacturing arm of the organization may use one DBS for its manufacturing control data while the financial arm may use another. The organization has, in fact, resorted to what might be termed separate functional data bases. Total integration obviously requires a very high level of planning, coordination, control, and DBS capabilities. The issue of what degree of data integration is most fruitful will depend upon the particular situation and characteristics of the organization concerned.

E. Prospects for DBS in the FMF

Concerning the employment of data base systems in the FMF in the period 1980-1990 some general observations can be made. By 1980 there will be numerous, well developed, commercially available DBS for the Marine Corps to consider. These will be offered by several different suppliers with varied philosophies and technical approaches. A choice of DBS will be available for the hardware of all the major computer manufacturers. Many of the products will be well tested in much actual usage.

Most important, there will be DBS alternatives that are well suited to all the sizes and types of ADPS components that will probably be found in a future FMF ADPS. Thus, not only will DBS be available for use at large general purpose computer installations, but also DBS will be available for small computers and their peripherals. Further, DBS use will not necessarily require the agency of skilled data processing personnel, but rather will be available to ordinary users through user-oriented languages that can be easily understood.

A DBS has the potential of addressing several of the problems and needs faced by an FMF ADPS. One such problem is the number of personnel required to perform the comparatively low-level data manipulation functions of data inputting, data editing, and so on. Currently, many man-hours by both data processing personnel and nondata processing personnel go into performing these activities. A DBS will offer features which, if properly designed and integrated to the overall ADPS, will work to make such activities more effective and efficient, thus actually freeing personnel as well as improving the quality of the processing performed by the ADPS.

Another perennial problem is that of errors in data. Data errors occurring at numerous points in the processing chain have been, and could remain, a serious problem of an FMF ADPS. Any well-conceived DBS will have an array of coordinated features and techniques devoted to the function of data control. With a DBS, the degree of control on data

quality can be expected to be significantly higher than it would be in a non-DBS system.

Timeliness of information is another matter that the coordinated facilities of a DBS can be expected to improve in comparison with a non-DBS system. Procedures for inputting data, transmitting it between files and nodes, sharing it among multiple users, and outputting it in reports should all be enhanced by a serviceable DBS. Related to the timeliness problem is the problem of harmonization of multiple copies of information. In today's systems it is common to have multiple files that should have identical information in them but that are, in fact, out of harmony. Often this is because some files are not as up to date as the others, and sometimes it is because discrepant data has been entered. One objective common to all DBS is the minimization of data redundancy. Multiple files of the same data are avoided whenever possible. As this is achieved, the problem of discordent files is greatly alleviated.

The use of a DBS can have beneficial implications for personnel training in the FMF. One effect of employing a DBS throughout an automated data system is that it introduces uniformity in languages and procedures for managing data. The same procedures and similar conventions would be in effect at any node or echelon in the ADPS. This means that a user's knowledge and training is transferable from one place in the system to another and from one application area to another. Thus, the burden of personnel orientation and training are lessened.

Not all effects of introducing a DBS into the FMF are outright simple benefits. The incorporation of a DBS into an ADPS can be an exceedingly consequential move. Depending on the scope of the ADPS and the nature of its operating environment, the DBS may be as significant an aspect of the system as the programming languages used, as the operating system, or as the hardware itself. A comprehensive DBS itself brings with it a whole new dimension of system organization. Furthermore, in order to support system-wide data base management, the remaining aspects of the system must exhibit a comparatively high degree of consistency and coordination. Thus, on both these counts the introduction of a DBS tends to result in a higher degree of overall system integration.

The suitability of more or less integrated data management within an FMF ADPS may depend upon matters beyond the scope of data processing per se. It may depend upon Marine Corps management and organizational philosophies governing the operation of the entire Marine Corps. For example, the degree to which detailed day-to-day management and control of resources is focused at the top of the Marine Corps as opposed to being distributed throughout the lower echelon operating units will have a bearing on the suitability and type of DBS capabilities. This is to say that fruitful introduction of a DBS may not be simply a technical matter, but may also hinge on wider organizational concerns.

Finally, the early optimistic visions of computerized data base management portrayed a situation where the totality of an organization's computerized data was incorporated into one single massive data base (perhaps physically distributed) to be managed in a fully automated on-line real-time manner by one computer or a coordinated set of computers. In view of the state of both data base theory and computing system technology today, this vision must be regarded as an ideal and somewhat grandiose concept. Some organizations with comparatively straightforward needs and with tractable operating environments may come close to realizing the ideal today or in the next few years. But earlier in this section it was noted that many large successful users of DBS have found it more satisfactory to take the approach of using multiple, separate, functional data bases rather than one massive monolithic data base.

In order to implement the ideal vision one must either create a completely centralized data base under the complete control of a centralized computer operation, or else he must face up to the technological challenges of a distributed data base and a distributed computer network. It is possible that a monolithic data base adequate to serve all the needs of a diverse community of users may be too complex to be feasible. We pointed out earlier in this section and in Section VII on system architecture that large-scale applications of distributed data bases and distributed computer networks are at the forefront of the state of the art. It will be at least 5 or 10 years before such applications are in any sense routine.

The above considerations argue that the FMF is not a candidate for a large monolithic data base in the early 1980's. This inference can be made in part because of the fundamental hierarchical nature of the FMF and the attendant separation of responsibilities, functions, and locations of FMF components. Furthermore, it is a consequence of the FMF's mission to constitute task-organized MAGTFs on demand to deploy to the combat ashore operating environment. Further, the demands of combat operations, the extreme geographical separations that can prevail between the objective area and main Marine Corps facilities, and the likelihood of insufficient communications capacity to and from the objective area all indicate that major segments of the FMF data base must be capable of service in detached and independent modes of operation.

All this does not imply, however, that the FMF ADPS should not employ a coordinated, uniform data base management approach throughout the entire FMF. Such an approach offers great benefits even though there may be multiple, separate, functional data bases serving the specific individual needs of FMF elements and commanders. Such an approach ensures compatibility between files and data bases; uniformity in data entry, edit, and validation procedures; similarity of data access and inquiry capabilities, and so on. User training, software development, hardware procurement, and day-to-day operations will all be benefited by such an approach.

Since much of the time, the FMF components are in the garrison environment, in which conditions are comparatively stable and units are in close proximity to one another, it may be attractive in garrison to employ data base management in a fairly centralized way. The FMF ADPS could be designed to exploit this fact, provided that it is also able to meet the data base management needs of the other operating environments. One approach to this would be to create adequate means for (a) spinning off separate and independent files and data base management processes whenever necessary, and (b) reconciling separate processing with the continuing centralized system as soon as feasible. The prime requirement for the overall feasibility of this approach is that the individual

ADPS user should be able to interface with the system in a uniform way regardless of whether the data base management support is being handled by the ADPS in the separated or in the centralized mode.

IV SOFTWARE TECHNOLOGY ASSESSMENT

Software costs have supplanted hardware costs as the dominant cost category in current ADP systems. That fact, alone, establishes software engineering as a critical consideration in ADPS development, even early in the concept formulation phase.[22,23] Several equally important software interests, however, extend the evaluation of software options well beyond a straightforward economic analysis. These concerns include: selection of application programming languages; effective implementation of the man-machine dialogue; responsive support and maintenance and interoperability.

Software refers to all computer programs (and their associated descriptive documentation) that give purpose and direction to computer hardware, tailoring it to serve the information needs of a user. Software technology embraces the information processing functions attainable with software, as well as the techniques used to specify, design, code, test, document, and maintain the computer programs that perform them.

Software includes both system software (operating systems, communications software, or computer center management aids) and application-related software (applications-development tools or applications software).

A. Current Software Status and Trends

For purposes of this discussion we will categorize software into four broad areas: Operating Systems, Language Facilities, Support Software, and Software Packages.

The trend of vendors of large main frames in current operating systems design emphasizes interactive time-shared activities, using virtual memory techniques and accommodating telecommunication and networking activities with increased consideration of security and access

control to the information contained within the system.[24] Other vendors are concentrating on a range of operating systems including those with simple serial batch, multiprogramming, multiprocessing, remote batch, interactive, and real-time capabilities. The most significant problem yet to be solved for the normal user of systems are the problems of the security and integrity of the system and the problem of networks and network protocol.

In the area of language facilities, the proliferation of new major application languages and of high level programming languages has slowed down and, for all practical purposes, in the commercial and scientific worlds has stopped. The current emphasis in the major high level languages, COBOL, FORTRAN, ALGOL and PL/1, as well as in BASIC, JOVIAL, LISP, and APL, is on standardization. In some instances these efforts will result in a second, or revised, standard which has come about after broad experience with the first version of the standard. A great deal of effort has gone into the testing and validation of the various vendor offerings. This has resulted in a higher degree of compatibility and transportability of the major languages across hardware types of a single vendor and between vendors. These activities will continue but are only of indirect interest for the FMF's ADPS activities.

Activity in support software has kept pace with operating system development and is concentrated on the revision of products such as the sort-merge routines, loaders, file copiers and updates, and library capabilities. These efforts have resulted in the increased reliability of these products. Additional support packages have increased in availability and utility. Packages such as debuggers and tracers, program analysis and program flow analysis and display, performance measuring and monitoring, precompilers, resource accounting and billing, and program and data set control or cataloging are all now generally available for major systems of most vendors' product lines.

One major factor in support software has been the entry of independent software manufacturers into the market place. This effort has resulted in more responsive and cost-effective support capabilities,

particularly tailored to specific application areas. Examples are SYNCSORT III, Johnson Job Accounting Report System, or ASSIST.

The significance to the FMF ADPS of trends in support software is that software is becoming more application and user oriented, more comprehensive, and that it is being developed in a competitive market with cost effectiveness as a primary objective.

There is a considerable overlap in the categories of support software and what are considered here as software program packages. Much support software is offered in packages, but the primary emphasis of software packages is on total application systems such as financial systems or inventory management systems. The provision of the complete set of programs and procedures to satisfy the requirements of a user in a broad application area is becoming more commonplace.[25] There have been packages on the market for some time that have been very effective in satisfying the needs of business in the area of financial management, accounting, and production control. For the company that does not have or does not want to support an expensive computer support staff including system designers and programmers and does not wish to suffer the long lead times required by in-house development of software systems, not to mention the use of additional hardware resources required by system development and test; the availability of software packages, consulting, support, and maintenance has proven an attractive alternative.

The existence of solutions to a broad range of problems in diverse application areas, and more important, the availability of the technology to supply comprehensive and reliable systems for specific application areas is of major significance to the FMF ADPS plans.

The utilization of the technology employed to design and implement these comprehensive and cost-effective application and user-oriented capabilities will provide the FMF with an integrated range of software that can be implemented on a complementary range of hardware to provide the ADPS tools to the FMF commanders and their staffs. The employment of all this software technology will also decrease the requirement for highly skilled and trained computer software support and maintenance

personnel in the FMF.[26] This technology will enhance the interaction of the user in the field with his ADPS tools and will allow a direct and local solution to operational problems beyond the scope of current FMF ADS support.

B. Software Technology Related to the FMF ADPS Development

The availability of a series of operating systems of increasing capability is of considerable consequence to the realistic and effective implementation of ADPS capabilities required by the FMF. The availability of operating systems to support serial processing, remote batch, and interactive applications on the scale of hardware configurations compatible with the FMF environment in garrison, afloat, and ashore is fast becoming a reality. The state of the art in operating systems will be sufficient to support Marine Corps requirements in the 1980s.

One of the major ADPS requirements will be for software technology to support the information processing and reporting requirements currently demanded by the Class I systems supporting the Functional Managers at Marine Corps Headquarters. These software functions will include more effective automated data capture and input; comprehensive data verification, correction and validation; and the capability to output the data formatted to satisfy the various objectives of its end users. There are currently available and under development a number of different types of software techniques to accomplish these objectives. These software capabilities range from programmable stand-alone terminals (for example, Datapoint 1100), to comprehensive interactive editors (for example, SUPERWYLBUR) to full-blown data management systems (for example, ABADAS). The solution of the data capture problems in the FMF is well within the technology of software development and with continued development will exhibit the necessary maintainability and portability required by the FMF operating environment.

The second major software requirement is the capability of accomplishing data storage, manipulation, and retrieval. FMF's information requirements may be effectively met if FMF units make full use of the

data captured for use in satisfying the reporting requirements of the Functional Managers. The following are several software capabilities that are necessary to satisfy these needs.

The primary tool required is a file maintenance capability. This capability includes building and controlling files; replacing, correcting, and appending information in the files; copying, converting, reformatting, and reordering of the files. This capability should also include access control, security, and integrity concerns with respect to the files being manipulated. These are all capabilities that to some degree have been accommodated by system support software or special purpose packages in the current ADP environment.

One of the additional tools required is a report generation capability. A very broad range in content and format is required in the information to be produced for FMF unit commanders from the files maintained in the system. Therefore, a simple-to-use, flexible or adaptable output producing capability must be supplied. A tool to produce lists, tables, tabulated, categorized and otherwise formatted displays is readily produceable by today's software technology and should not represent a major challenge to the FMF ADPS system designers.

Another tool that will contribute greatly to making the FMF ADPS a dynamic and responsive answer to operational information needs is one that will use the stored-data in a selective query and response mode. That is, it will have the ability to retrieve data in a selective or discriminating way as opposed to getting a complete disgorgement on some particular aspect or set of attributes stored in the system.

This tool should take advantage of the user orientation developed in the software design and the responsiveness of the hardware, as well as the depth of information available locally. A simple example of the use of this type of tool would entail asking the system for a list of data on all master sergeants who speak Chinese, have a secondary MOS in electronics, have never had malaria, and have at least 3 years left on their enlistment. After receiving an almost immediate response from the system in hard-copy, one might then ask for those on the list who have

red hair and are left-handed. The software technology to provide such a tool is available in general today, and the efforts to adapt or integrate this tool into the FMF ADPS environment will be very nearly the same as the effort being made to extend these capabilities to the general user community in an economic way.

The final basic tool for data manipulation is an analysis capability. Certainly at the intermediate and upper echelon levels there will be the need for interpretation and manipulation of the available data, both numeric and alphanumeric. The user will want to establish averages and means; maximums and minimums; reordering, logical comparisons, and combinations; cover tabulations, graphical presentations, and in fact a full range of statistical procedures. This software technology has traditionally been a primary objective of software development and generally exists in current large scale conventional computing centers and has been implemented for a wide range of computer users. The trend in the software technology has been to provide these capabilities on a wider range of hardware configuration and especially for the non-EDP oriented user: social scientists, doctors, sales managers, plant managers, and so on. It is well within the state of the art to be able to provide this tool to Marine Corps users in the 1980s in system configurations compatible with the FMF environment.

We have considered file maintenance, report generation, query/response, and analysis as individual software factors. In fact, while they have developed individually and can be considered individual components, more recently they are being approached as integral parts for what are variously known as information storage and retrieval systems or data base management systems. There are several commercial products currently on the market which have successfully provided several of these attributes in a single package (for example, RE-ACT, System 2000, MINIDATA, DATA DIALOG, JANUS, and DATATEST). The trends in this area of software technology will significantly impact the realization of a viable system that meets large segments of the FMF's ADPS requirements with the appropriate user considerations and hardware configuration constraints.

An additional software facility that should be considered with respect to enhancing the FMF ADPS utilization is the ability to handle narrative or textual information. The capability of handling documentation in the form of manuals, directives, orders, and so on, is readily available. We assume that the ability to transfer machine-readable information between the levels of hierarchy of the FMF ADPS would exist. There are perhaps instances where it would be more effective to transfer or distribute information in this format as opposed to printed matter or microfilm. Certainly, the capability of formatting and modifying such things as orders (promotions, leave, shipping, and so on) and other frequently used letters, order forms, or documents could be an intrinsic feature on practically all levels of ADPS in the FMF.

Another aspect of software technology significant to the FMF would be the availability of resource use routines and performance-measurement packages. The availability of this type of tool would make the planning and design of any proposed system considerably more accurate, with a higher confidence level in the cost and performance projections.[27] These software components would be incorporated as an integrated part of the ADPS in the upper levels of the hierarchy and would extend downward through the hierarchy in lesser degrees of sophistication. Perhaps at the lowest level these routines could be used on a cyclic or spot-check basis to further ensure that resource use and performance are consistent with the design expectations.[27]

V REVIEW OF NONAUTOMATED ADPS PROCEDURES

If there is any aspect of an ADPS that is likely to be inadvertantly ignored, it is the area of nonautomated procedures. These are procedures that fall within the boundaries of the system but that are performed by human beings rather than by machines and equipment.

There are several reasons why nonautomated procedures are overlooked. First, when automation is initially introduced into an environment, the newly introduced automated procedures are the primary focus of interest, and there is a natural tendency to refer to just the automated portion as "the system." But seldom do the automated procedures alone constitute a complete functional unit. A more useful view usually results when the conceptual system boundaries are drawn to include those nonautomated procedures that interact closely with the automated ones.[29,30]

Another reason for wrongly ignoring nonautomated procedures is that some may be so commonplace that they are not considered significant. Consider, for example, procedures for controlling personnel access to the interior of a computer center. Access may be granted simply on the basis of face-to-face recognition of the person seeking entry. But this is such a commonplace approach that it may not be seen as one specific procedural solution to a situation that could be handled in other ways.

Procedures are also overlooked because the need for them may not be apparent. The need for explicit procedures to protect storage media and computing machinery from fire or water damage may not be recognized before an accident occurs. Similarly, the need for more effective file backup procedures may not be recognized until a catastrophic operating system failure inflicts losses.

The study of the <u>technology</u> of nonautomated ADPS procedures traditionally falls more in the domain of the management sciences than the information sciences. Such a study is somewhat less systematic and

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technical than knowledge in such areas as hardware and software, and it covers a diverse set of concerns. Much of the information has been gained through the practical experience of people in the ADP field. Nevertheless, the technology of nonautomated ADPS procedures should be recognized as an area that can make the difference between an ADPS that meets its objectives and one that does not.

It should be borne in mind that the same procedure or function can often be implemented in either an automated or nonautomated way. Thus, in any given ADPS some of the nonautomated procedures could easily be candidates for automation if the system design were altered accordingly. An example is the logging of jobs run on a computer. In one ADPS this may be a manual operating procedure performed entirely by the computer operator; in another it may be fully automated under control of the computer operating system. The important point remains that in any given ADPS one should not overlook whatever nonautomated procedures are properly part of the system.

For the purpose of discussion, SRI has grouped nonautomated procedures into several categories. The role of the categories is simply to ensure that significant areas of procedural concern are considered, and not to require that procedures fall clearly into one or the other of these categories. The categories chosen for discussion of manual ADPS procedures are:

- Operating procedures
- Security procedures
- Data management procedures
- Software management procedures
- Backup procedures.

A. Operating Proceudres

Under the umbrella of operating procedures, SRI has investigated two areas of procedural interest that significantly influence the formulation of ADPS concepts. One area deals with the organizational management philosophy regarding access to, and use of, computer power and

computerized data. Procedural concepts at this high level establish basic facility and organizational interrelationships--primarily between the ADPS user population and the ADPS. Such interrelationships are closely coupled to system architectures which implement and formalize them.

The other area embraces such data processing center activities as powering up and shutting down computers; loading, and unloading cards, tapes, and paper from I/O units; initiating computing jobs, monitoring the progress of computations, and so on. These are more characteristic of the internal workings of an ADPS, and especially, of the interrelationship between the computer operator and the computer capability.

1. Organizational Operating Procedures

An overriding issue concerning organizational operating procedures is the centralization or decentralization of management authority and responsibility for ADPS services. Centralization is appropriately associated with rather large computer facilities with attendant large and diverse staffs. The emphasis is on providing a broad set of rather powerful services to a diverse group of users. Centralization is usually attended by comparatively formal procedures for user access to computing services. The centralized system does not lend itself particularly well to meeting the small, ad hoc, spontaneous, highly personal computing needs of users.

Decentralization is associated with some time-shared or interactive system capability that puts the user in closer contact with the computing system--without the buffering or intermediary of the data processing staff for each access. The services that it can provide range from those of the large centralized system (although generally at a greater cost per unit of work) to more individualized applications accessed from different levels within an organization.

It is apparent that within an organization as diverse as the Marine Corps, elements of centralized and decentralized management authority and responsibility will both exist. Centralization, from the

point of view of procedures, has the advantage of efficiency in the processing of large numbers of applications whose schedule is fairly regular and in which the user does not demand fast response. It has the disadvantage of comparative rigidity in meeting the unique, spontaneous needs of small users.

Decentralization, from the point of view of procedures, offers the advantages of more immediate response to user needs, an extension in the applications of computing, and direct user control that promotes interest and motivation. Disadvantages include the potential for duplication of facilities and activities, possible lack of uniformity within the organization, and possible increased total data system cost.

Certainly the centralization/decentralization of authority and responsibility within an ADPS is not determined solely by operating procedures. There are also strong architectural and hardware implications in this question as well. However, in the concept development stage of ADPS it is certainly beneficial to be cognizant of the influence of nonautomated organizational operating procedures.

2. Computer Operating Procedures

Currently, computer operating procedures in medium and large installations tend to be quite highly developed and well organized. The objective of such data processing centers is almost always to maximize throughput. This objective is met primarily through the use of sophisticated operating systems on computers which are monitored and maintained by a highly technical staff.

Such modes of operation foster operation staffs that are specialized and set apart within the organization. Numerous automated aids have been developed to aid the operator perform his job. These include computer-generated console logs, cathode ray tube operator's displays, self-threading tape transport units, automated input-output assignment by the operating system, and so on.

An area in which nonautomated operating procedures are of significant concern is that of mini- and micro-computers. With these

small computers it again makes considerable sense for the user himself to engage in handson operation of a computing resource. In this environment, however, the user is likely to be a manager or user of management information rather than a data processing specialist. The problem then becomes one of establishing procedures for making the data processing component easy to use as well as technically transparent to the user.

Much of the capability in this area will depend on the software engineer's ability to implement conversation-like languages and so on, but in some instances it is primarily the proper design of nonautomated user-oriented procedures that will aid the user. Take, for example, the entry of data of various formats. Automated cueing of formatted responses by the user can supplant the use of large, bulky instruction booklets, and inexpensive solution replaces a slow and cumbersome user procedure with one that is more streamlined and more productive.

B. Security Procedures

Rarely have data or programs been treated with the care commensurate with their potential value to an organization. In many cases computer centers are wide open to visitors, programs and computer output are filed within arm's reach of the passerby, and operations are placed in locations subject to hazard from natural or man-made disaster.

In the past 5 years, not only have the risks associated with conventional hazards--theft, vandalism, fire, flood, power interruption, operator blunders, and so on--been given due attention, but numerous risks growing out of the computing technology itself have been recognized. An example of the latter is provided by timesharing; with the computer servicing several users simultaneously, there is a vital need to prevent one user's job from interferring accidentally or by design with the work of others.

Two broad classes of security are recognized. One concerns the safety of facilities and equipment; the other concerns the safeguarding of data and information. Whereas a great many modern-day security features are either built into the system configuration or are in the form of

small computers it again makes considerable sense for the user himself to engage in handson operation of a computing resource. In this environment, however, the user is likely to be a manager or user of management information rather than a data processing specialist. The problem then becomes one of establishing procedures for making the data processing component easy to use as well as technically transparent to the user.

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Two broad classes of security are recognized. One concerns the safety of facilities and equipment; the other concerns the safeguarding of data and information. Whereas a great many modern-day security features are either built into the system configuration or are in the form of

automated procedures, a significant portion are manual procedures. Some security functions depending strongly on manual procedures are physical access control to ADPS facilities, user identification and authorization, management of computer storage media, logging and physical control of computer jobs and output, facility inspections, the monitoring of modifications in hardware or software.

Currently such areas are the object of widespread theoretical and practical attention. This will result in some solutions that are not manual procedures, but the latter will remain an important component. By nature, security depends upon a range of measures; no one type of measure can be slighted, for security tends to be only as good as the weakest link.

The nonautomated procedures called for in future ADPS will generally be somewhat prosaic in themselves, but to be effective they will have to fit in well with the systems' built-in security features and with automated security procedures, and they must be systematically and comprehensively applied. This implies that they must be provided for in the initial system design, not introduced as an afterthought.

Manual security procedures in several areas are of particular concern for an FMF ADPS, for example, procedures related to the possible capture of ADPS equipment by enemy forces. Such capture could provide the enemy with valuable data files or with access to the FMF ADPS. The ADPS design should include procedures for minimizing the vulnerability of files and equipment operating in an objective area as well as procedures that would deny the enemy use of ADPS resources should they fall into his hands. This is a new problem because only recently has the ADP technology provided equipment that could follow troops to the field. There appears to be no easy solution.

The FMF ADPS will be subject to legal requirements, such as those laid down by the Privacy Act, concerning how certain information is protected and released to users. While some of this control will be implemented by hardware and software features, a significant component should

be provided by nonautomated procedures having to do with authorization of access, identification of users, documentation of information use, and so on.

An ADPS that serves lower echelons throughout all phases of deployment will necessarily interface with the Marine Corps communications system. The security of data transmission will be at issue, as will the security of interfaces themselves. Appropriate security procedures for accessing and using the communications facilities will be required of any ADPS design.

C. Data Management Procedures

Data base systems technology is addressed in detail in Section III. There, reference is made to the data base administrator, whose functions are crucial to the success of any large shared data base. In the context of a data base system (DBS) the data base administrator executes a number of nonautomated procedures in connection with such activities as:

- Approval of requests for data to be entered into the data base
- Approval of changes to data base management software
- Authorization of user access to the data base
- Analysis of statistics on data base usage, access, and performance
- Monitoring of DBS documentation for completeness and quality.

Although the future FMF ADPS may entail use of large, centralized, shared data bases and a comprehensive DBS only at the higher echelon levels, there will still be an unquestionable need for uniform data management approaches and practices throughout the FMF down to the lowest levels. Such uniformity must be reflected in the nonautomated data management procedures.

At the lower levels the nonautomated data management procedures that must be suitably designed and implemented include such things as:

- Manual error correction procedures for data rejected as the result of editing at the point of data entry

- Proper physical storage procedures for tapes, diskettes, cassettes, or other storage media
- Adequate bookkeeping procedures to keep track of the contents of data files, which may exist in multiple versions
- Documentation procedures to ensure that data formats, file contents, data reporting cycles, and so on remain compatible throughout the FMF.

Since input data is the commodity that necessarily flows from the arena of human operational and management activities of the FMF across the interface into the automated portion of the FMF ADPS, a significant component of nonautomated (manual) data management procedures will always be present. These should be considered and designed as an important integral part of the FMF ADPS.

D. Software Management Procedures

In today's user-oriented ADP systems the nonautomated software management procedures are concerned with such things as:

- Installing updates into existing software
- Maintaining records of the status of software in use
- Maintaining user-oriented documentation of software
- Recording data on software failures for use in maintenance activities
- Submitting programs for entry into system libraries.

and so on.

The general approach to software management in ADPS has been to impose conventions and standards upon systems programmers, applications programmers, and operations personnel whenever they prepare and submit software for processing by the ADPS. In some cases these conventions and standards are enforced by automated components of the system, such as language compilers, but in other cases such standards must be enforced by manual monitoring procedures. For example, perhaps no update to the computer operating system can be made without obtaining several levels of approval within the organization. This requirement might be backed

up by an automated auditing program capable of detecting an unauthorized modification if it were made.

In an FMF ADPS, software management procedures must play an important role in creating a balance between uniformity and flexibility of ADPS capabilities. Software facilities available at one point in the organization should be available at other points with similar needs. Thus, the software management procedures must preserve compatibility and sharability of software throughout the ADPS. It would be unsatisfactory, for instance, if a given application could not be run on two identical computers because the software management procedures had permitted the two computers' internal software to become divergent.

Many of the nonautomated procedures of software management entail recordkeeping concerning the status of software elements in use. Keeping the user-oriented software manuals or instructions current falls in this category. In an FMF ADPS such bookkeeping must be straightforward and easy to perform in the course of day-to-day administrative and military activities.

In any ADPS with many widely dispersed facilities such as the FMF ADPS will have, the role of nonautomated software management procedures is very important in sustaining system-wide operability over an extended period.

E. Backup Procedures

In broadest terms backup procedures address the problem of reinitiating operations or reestablishing data and information after some kind of interruptive or destructive event. This could be a power failure, a natural disaster, or an attack by hostile parties. It could be the result of bugs in the operating system, a faulty application program, or a deliberately destructive user program.

As with other areas of procedures, backup procedures were initially very primitive. But in these days of multiprogramming, multiprocessing, interactive computing, shared files and memories, multiple job streams,

valuable private files, huge tape libraries, and so on, the problems of adequate backup are quite severe, and manual procedures for backup may be quite elaborate.

Among such procedures should be provisions for shifting loads to alternative computers; creating, storing, and protecting redundant copies of storage media; replacement of key systems; initiation of checkpoint-restart operations; and so on.

Today, there is a natural trend toward shifting the burden of backup from nonautomated to automated means. As systems become more highly organized, the system itself can often handle backup activities more efficiently than can a human through manual intervention. However, in any given situation there are usually types of backup provisions that are best implemented by manual procedures. This may be particularly true for any future FMF ADPS. Often highly automated backup presupposes a highly stable and controllable system operating environment. The very opposite characteristics prevail in the combat ashore environment of a MAGTF. There, manually implemented backup of several different types is certain.

VI TELECOMMUNICATIONS TECHNOLOGY

A. Introduction

In the FMF garrison environment, telecommunications is facilitated by the availablity of telephone wires and a range of Marine Corps base utilities. For this reason, the deployed environment is the critical concern.

Telecommunications support of ADPS for the deployed FMF in the 1980's will be incorporated as part of the Landing Force Integrated Communications System (LFICS),[31] which is a basic systems communications plan that is meant to guide the future development of interoperable tactical data systems and communications equipment over the next 15 years. As such, LFICS specifies the timely introduction of newly developed tactical communications equipment and allows for an orderly transition toward the secure, digital communications environment envisioned for the 1980's. It is intended to eliminate unnecessary duplicate development of system-unique communications equipment.

LFICS is coordinated with the Joint Tactical Communications (TRI-TAC) Office which has the basic design goal of a fully digital communications environment. LFICS is also coordinated with the Navy communications system, as well as relevant portions of other Services' communications system. One of the implications of these associations is that the equipment suite for LFICS will make maximum use of TRI-TAC developed equipment and off-the-shelf communications equipment.

The central question that has been examined--with regard to introducing ADP systems into the FMF organization--is the compatibility of desirable system topologies and data transfer capacities with the goal and the emerging implementations of the LFICS. SRI's analysis of that question has concluded that the LFICS concept and equipment will not substantially constrain the ADPS topology and data-link options, with the following qualifications:

* The Unit Level Message Switch (ULMS), part of the Unit Level Switch development, currently under development will provide the capability to process both data and JANAP 128 formatted message traffic. The ULMS acquisition schedule calls for attaining this capability in the late 1980s.

* Security of data transfer presents security problems somewhat different from those of voice communications. These are not adequately covered under LFICS, and they are a problem to be considered in the ADP system design.

This conclusion is supported and validated by SRI's interaction with the C^3 Division at MCDEC that is responsible for managing LFICS development. Results of that interaction include:

* Mutual agreement that the LFICS digital switching metwork of the post 1985 timeframe will adequately support the alternative ADPS concepts that SRI has generated (see Volume IV), and that channel capacities and data links of nearer term LFICS configurations could provide substantial support to these concepts.

* The ship-to-shore telecommunication support for ADP systems is not included in LFICS and must be addressed in a separate planning effort.

The former point is the result of computer simulation exercises of the switched, digital post-1985 communications environment run by MCDEC on its LFICS simulation model. Data needed for those simulations were provided by SRI.

A related constraint, not necessarily a product of LFICS, is the current state of the art in on-line coupling of computers through sophisticated telecommunication networks.[32-34] It is felt that such concepts (for example, the ARPANET) are at the leading edge of technology and that they introduce a host of unresolved problems concerning communications operating systems, message management and network supervision, as well as basic problems in reliability, security, and recovery. These factors should not, however, be viewed with undue concern since such tight network coupling offers little potential benefit for the FMF type of organization over conventional (and mature) approaches based on a store and

forward coupling between separate processors. (Linking of terminals to processors can be accomodated for on-line interaction without significant problems.)

The comments just concluded apply primarily to intra-theatre, shorter-range support of ADPS for the FMF. The primary extra-theatre telecommunications between higher FMF headquarters and the Supporting Establishment will be through AUTODIN. The AUTODIN system itself provides no obstacles (other than accessibility and message priority) to the flow of administrative data of the type associated with FMF ADPS.

B. Technical Considerations

SRI examined, in detail, the functional relationship between ADPS and telecommunications; those relationships are described in the Appendix. Rather than duplicate that effort in this section, the following paragraphs will discuss technical considerations related to four primary telecommunications functions. These discussions are intended to complement and focus the information contained in the Appendix.

1. Transmission

Transmission links use some form of electromagnetic signals to convey information through space. A variety of media is now available for this purpose--wire, terrestrial radio, and satellite radio. Radio transmission is particularly attractive to the Marine Corps because of its ability to support mobile activity. For this reason, a wide variety of mobile radio equipment is already deployed, and additional equipment is being developed or planned. Man-packable, team-packable, and truck-mobile units are, or will be, available to cover many modes of operation.

VHF (very high frequency) and UHF (ultra high frequency) bands are used for LOS (line-of-sight) transmissions, but UHF LOS includes satellite circuits, so that effectively thousands of miles of coverage are possible, even from suitable man-pack equipment. The HF (high frequency) band is used for long distance (thousands of miles) circuits.

Because of the increased availability of VHF and UHF bandwidth, and the relative stability of the transmission mechanism (LOS), these bands are most suitable for transmission of digital signals, hence data transmission. Such is not the case with HF transmission which is an inferior data transmission mechanism.

Currently, the Marine Corps transmission links emphasize the use of analog signals, and are commonly used for voice signals. With the advent of LFICS, the 1980's will see a transition to digital transmission, even for voice. A major aspect of digital transmission is the relative ease (compared with analog) with which encryption can be applied, especially for voice. A major thrust of LFICS is secure voice.

In particular, LFICS is moving toward a standard 16 kbps (kilobit per second) transmission channel building block. This channel capacity should be quite suitable for most data communications applications of the FMF ADPS.

2. Switching

Current networks employ dedicated (that is, non-switched) facilities, manual or automatic (relay) circuit switching, or manual devices (torn-tape).

During the 1980s, the advent of LFICS will cause a transition in switching. Electronic circuit switches and electronic message switches that will operate in a coordinated manner with the circuit switches will be introduced. All switches will accommodate the transmission of 16 kbps data streams. The transition to electronic and message switches at higher headquarters (MAF, Division, and Wing) will be satisfied with large automatic switches, that is AN/TYC-39 circuit and store and forward switches, and will occur in the mid 1980s. The transition to digital unit level switches (both circuit and message) will occur in the late 1980s for all units below the Division/Wing level.

Among the advantages of the new switches are decreased weight, power and volume needs, increased capacity, speed and reliability. The ULMS should provide support to the efficient communication of interactive terminal traffic.

Dedicated circuits will initially be used to interconnect nodes of the Marine Air Ground Intelligence System (MAGIS). However, the other MTACC systems will be implemented so as to use the common user communications system specified in LFICS.

It is anticipated that the ADPS will not need to use dedicated circuits but will use switched circuits either via message or packet switching. Packet switching, if used, would serve fast response traffic related to real-time operation of the interactive terminals. Message switching would serve the slower response needs of bulk data transfer (files or records) between processors of the ADPS.

3. Terminals

The ADPS will probably need three types of terminals to enter and receive data transmissions. These are displays with keyboards, receive-only serial or line printers, and teletypewriters (or facsimile).

4. Security

A major advancement of LFICS is the strong emphasis on communication security for both voice and data. The use of digital transmission (as opposed to analog) makes possible the extensive, economic, and practical use of encryption and decryption devices.

While communication security is an essential ingredient for a secure ADPS, it is not sufficient. Further measures may be needed to protect the total security of the ADPS, especially the data bases, from unauthorized inspection or alteration. There is concern about the potential for unauthorized use or access to terminals (especially those with input capability) or computer systems themselves. Of particular concern is

the capture (known or unknown) intact by an enemy of terminals or remote computer systems. The security issue is addressed in more detail in Volume IV of this report.

VII SYSTEM ARCHITECTURES

A. The Meaning of System Architecture

"Architecture" is a term that can be applied with somewhat different meaning both to an individual computer and to an entire ADPS. In the section we are concerned not with individual computers but with the architecture of complete systems.

For the current study the system architecture of an ADPS is defined as the macrostructure of the ADPS. It is the structure that is determined by the dominant features and elements of the system rather than by the details of its design. If one has a description of the architecture of an ADPS, he can infer many of the system's important characteristics.

There is no clear boundary between system architecture and the more detailed aspects of an ADPS design. If one begins with a system architecture description and elaborates it by making it more detailed, he is proceeding toward a complete design description. He would ultimately, however, also have to include detailed information on the other major system aspects, namely, hardware, software, data base management, nonautomated procedures, and communications.

One category of system features that stongly determine system architecture consists of the physical components from which the system is assembled. In the present context these are such entities as processors (computers), terminals, files, and communications links. Additional types and subclasses of entities may be involved as well.

Another class of architectural features consists of the topological and spatial configuration of the system. Such properties as the relative positions of components, the interconnections between components, and intercomponent distances are among these.

Since two ADPS having the same types of physical components distributed and interconnected in the same way can have quite different functional characteristics, a third class of features determining architecture consists of the functional features. For the FMF ADPS such features include the major operations and transformations performable at each system node, the modes of information transfer possible across system links, and the information flow paths supported by the system.

A final class of determinants of ADPS architecture consists of the major performance characteristics of the system. These have to do with the sizes and speeds of system components and the capacities, or volumes, of various system functions. Also, such features as power requirements and required operating conditions may be included

B. The Current State of ADPS Architecture Technology

Several technological developments are strongly influencing the shape of innovative ADPS architecture today. One of these is the mating of communications technology with computing technology. For 10 or 15 years the prospects for doing this have been well recognized, but it is only in the past 5 or 6 years that an adequate array of hardware devices, software components, and systems philosophies have been available to support teleprocessing as an attractive option in many environments.

Another strong influence on current system architectures is the present-day ability to distribute processing capability throughout a system. Such distribution takes two forms: the physical placement of processors at various points throughout a system, and the incorporation of processing "intelligence" into heretofore unintelligent devices. The ability to distribute processing power has resulted from several developments in the technological marketplace in addition to the already cited mating of computing and telecommunications. One of these is the proliferation of processor sizes and types. In the past 2 or 3 years this has been most notable in the mini- and microcomputer areas. The whole spectrum of small and very small computers is now richly populated. This extends to the microprocessors, which are commonly integrated into other devices.

Another contributory development is the proliferation of peripheral devices, particularly for input-output. This development makes it possible to match peripheral capabilities to the capabilities of processors of any size and type at any point in a distributed system.

A third strong influence on today's ADPS architecture is the feasibility of developing so-called "mixed systems." These are systems composed of components furnished by a variety of suppliers rather than by one vendor only. In earlier days the interfacing of components from different suppliers often posed problems that made the task unattractive for the customer. Today, there are many histories of successful mixed-system developments, and such systems are becoming the rule.

The technological influences described above have accounted for a major current thrust in ADPS architecture, namely the design of large distributed computer systems, or computer networks. These are systems that depend on data communications links as well as direct connections between computers and between peripherals and computers. They embody a number of computers, usually in a range of sizes and characteristics. They usually employ either a distributed data base or a centralized data base that is accessed remotely.

One driving motive behind the creation of such systems is to bring data processing capability to the location of the user, to the location where the work is most naturally done.

C. Future Directions in ADPS Architecture

The current emphasis on distributed computing networks has pointed up some problems that will impede progress in this direction. The more tightly coupled a computer network is, that is, the more the network is required to perform under unified automated control in real time, the more difficult are the network control problems. Many problems in this area are as yet unsolved and are the object of active research and experimentation. In the next few years one can expect that distributed ADS architectures will be elaborated as solutions to network control problems are developed.

The second major problematical area for distributed architectures is that of system integrity and security. Distributed systems, because they are geographically dispersed, because they combine the world of communications with that of data processing, and because they support a comparatively high degree of concurrent, or parallel, activity, are subject to accidental and intentional breaches of integrity and security to a degree that more centralized and more closely contained systems are not.

In the next 2 to 5 years one can expect considerable progress in approaches for enhancing integrity and security. As fast as these approaches are developed, distributed systems making use of them will be developed for use in sensitive military and commercial environments that demand a high degree of system integrity and security.

Appendix

TELECOMMUNICATIONS AND ADPS

Appendix

TELLECOMMUNICATIONS AND ADPS

1. Introduction

An ADPS consists of a balanced set of functional hardware elements such as processors, mass storage units, and input/output terminal devices, as well as various software elements. In a centralized system the hardware elements are within tens or hundreds of feet of one another, interconnected by multiconductor computer system cable.

In a decentralized system some elements may be separated by thousands of miles. Especially affected are the distances between processors and terminals, processors and files retained in mass storage units, and processors and processors. Here the elements are interconnected by a telecommunications system of transmission links (such as wire, radio, or satellite) and communication switching units.

In practice, most large-scale ADPS exhibit a mix of centralized and decentralized components. Systems are designed so that the emphasis of the mix can shift with time as requirements and technology demand and permit. Several factors influence the decision between centralization and decentralization. Among them are: costs, availability of resources (especially telecommunications), system effectiveness, system responsiveness, support, and maintenance.

This appendix is primarily concerned with the telecommunication aspects of large-scale ADPS. The following topics are covered:

- The role of telecommunications in ADPS
- The elements of a data communication system
- Data transmission
- Data switching
- Data terminals
- Data traffic

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- Data networks
- Marine Corps trends in data communications
- Potential requirements of data communications in FMF ADPS.

The purpose of the appendix is to identify those elements of data communication critical to the FMF's needs, to characterize such elements, to describe the tradeoffs associated with them, and to relate all of these aspects to the current Marine Corps telecommunication development plans.

2. Telecommunications for ADPS

a. Geographic Dispersion of ADPS Elements

Current and projected technology dictates the manner and degree of geographic dispersion of the various hardware elements of an ADPS. For reasons of signaling speed, bandwidth, and techniques of control, a processor will be co-located with an associated set of elements that includes main memory, mass memories, an assortment of peripheral devices, and the programs to control that processor. Terminals, data files, and other system processors can be located at a distance and coupled to the host processor via data communication facilities.

Simple terminals (such as a teletypewriter) may couple directly to the communication facility. Complex terminals (such as CRT displays with graphics or text editing capabilities) and mass stores (such as disks) often have sufficiently complex control needs that they must be coupled directly to an intermediary processor which, in turn, is coupled to the communication facility. The dual role of processors (host or coupler) should be recognized, but it should not be a matter of undue concern for purposes of functional analysis. Practically, however, there are substantial tradeoffs of cost, portability, and reliability.

In a performance comparison with direct intra-system links, data communication links often:

- Have a low information throughput rate
- Use only a single channel for serial transmission of information

- Take longer to propagate a signal
- Have higher error rates
- Are more likely to fail
- Are more susceptible to misuse.

Data communications links are also typically more costly.

One must expect, therefore, the convenience of a telecommunications system to be somewhat tempered by problems inherent in that system, as well as by some considerations of cost and maintenance. Certainly, this is one aspect of the tradeoff between centralized and decentralized computing system architectures.

b. Processing of Information

Information is processed by processors under program control. For reasons of simplicity, the stimuli for processing will be regarded as due to information input via a terminal. Thus, an operator initiates activity by entering data or by requesting stored information. From such a terminal input, complex chains of events may result, in which processors activate other processors, files in mass storage are searched, retrieved, and altered, and other processing tasks are created for automatic execution at some later time.

Explicitly, or implicitly (without any awareness on the part of the terminal operator) specific programs may be exercised, and specific items of data (local or distant) may be accessed and/or altered.

By means of automatically controlled program and hardware multiplexing action, a given processor may concurrently share many terminals. This mode of operation is referred to as time sharing, and it is the basis for widespread interactive use of the central host processor. If sufficiently fast, a time-shared processor can provide a terminal operator with the impression that no other terminals are concurrently being served.

c. Data Bases

Informally, a data base is an aggregation of data held in a mass store of the system. Within an ADPS, operations involving the data bases are the primary focus of processing activity. One processor may need the data contained in the base of another processor remotely located from the first; or, a terminal inquiry or action may require access to a data base for purposes of reading or alteration. As a result of these activities, data traffic patterns and volumes within a network of ADPS processors and terminals are directly affected by the use and the geographic distribution of the data bases.

Within data bases themselves, the data are organized into disjoint sets called files. Each file is usually further subdivided into records, which may contain one or more data elements. File, record, or element names or locations are used to uniquely identify specific items of information in a system. Such attributes, or addresses, are used by the telecommunications control programs to locate information and to store data.

Normally information in a data base remains there intact (barring a system failure) until it is either erased, overwritten, or marked as unavailable as a result of some explicit system action. When stored on a removable storage medium (reel of magnetic tape, pack of magnetic disks, diskcartridge, diskette, cassette of magnetic tape) the data may be physically removed from the system and then be inaccessible for system use until it is manually replaced in the system.

Access to information in a data base may be for purposes of reading only, or for writing or altering. Inquiries made of an ADPS generally involve reading only, as may the generation of printed reports. Inputs of new status generally involve the overwriting of old information with new, or simply the recording of new information.

In a network system, if a processor requires data not in its own data base, it can request the data from a linked processor that has the data base. The latter processor can then execute the reading and

pass, via a data communication link, the read data to the requesting processor. In a related manner, data can be written in a remote data base. Linked ADPS elements, thus, permit the flexibility of dispersed data--without the duplicate storage of information at various system nodes.

d. Terminals

Terminals are hardware used to couple users to an ADPS. There are six major classes of terminal devices, as listed in Table 6. Depending upon the nature of a specific device, it may accommodate input from a user, provide output to a user, or both. A wide variety of terminals exists for accomplishing each function. A major distinction between output processes are: (1) "hardcopy" in which the results are recorded on paper (constituting a written record) or (2) "softcopy" in which a transient visual or acoustic image (or signal) is created, to be retained only by the memory of the user.

Softcopy is often used when no written record is needed but high speed and response is desired. Essentially the record may be retained in the mass store of the ADPS, available upon demand. Typically, softcopy terminal devices are used in an interactive manner by system users.

With computer controlled output, an interactive process commonly aids the operator during input. Under program control, the system can pose questions, indicate alternatives, and immediately flag detected input errors. The operator can also change recent input to correct errors and immediately see the results of the correction. To be effective the system's response to an operator must be written within a few seconds to avoid problems of operator frustration and distraction.

Not all operator input need result in immediate output to the terminal. Thus, a complex analysis can be requested and the system permitted to execute it when resources are available--without further operator intervention. Such an operating mode is termed batch processing.

Table 6

TERMINAL DEVICES

DEVICE	INPUT PROCESS	OUTPUT PROCESS	COMMON APPLICATION	COMMENTS
Teletypewriter	Operator entry of data via keyboard	Mechanized printing on paper	Inquiry-response, low volume requirement. Message generation with hardcopy required for record	Electromechanical. Output rates to 100 or more characters/sec
Receive only Printer	None	Mechanical printing on paper	High volume use. Production of reports or messages	Electromechanical. Output rates to 2000 characters/sec
Displays	Operator entry of data via keyboard	Visual images (e.g., text) drawn upon a cathode ray tube or a gas panel	Inquiry-response with high volume response. Message generation. No need for hardcopy record	Electronic. Needs no supporting supplies. Fast operation. Output rates in excess of 100,000 characters/sec
Data readers	Previously encoded data (e.g., magnetic stripe) read when document placed in reader	None	Entry of often used fixed data such as personal or unit ID, part numbers, canned messages	Provides rapid entry of repetitive data, e.g., for inventory control
Audio response	None, or telephone touchpad	Acoustic signals, usually spoken word in response to coded digital messages	Inquiry-responses to users equipped only with telephone instrument. Limited volume of activity	In commercial production Adequate quality of spoken word. Flexible vocabulary and language
Voice analysis	Spoken word converted to coded representation of each work for computer analysis	None	Low skill, convenient rapid, low error rate data input	Still in research stage.

Batch processing initiated from a remote terminal is termed remote job entry.

Among the interesting aspects of operator use of a terminal are these: (1) operator input (hence computer output) tends to occur in bursts as the operator alternately inputs data, reads the result, thinks, and then resumes input activity, (2) the functional task being performed with the terminal change during the day so that different programs, data bases and systems may need to be used by the same terminal, and (3) just as with a telephone, terminals may be inactive for extended periods.

All these aspects influence the characteristics of the terminals' data traffic--which, in turn, influences the nature of the supporting data communications network. The network is particularly sensitive to: (1) the rate of information flow through the network, and (2) the rate at which information has to be routed from source to destination. The former impacts the transmission links and the latter the network switches.

Terminals, in particular, "stress" a data communications network because the large ratio of peak-to-average data rate can lead to requirements of large and costly transmission links, and because the burst nature of the traffic can present high switching rate demands upon switches, leading to requirements for large capacity, costly switches.

3. Elements of a Data Communication Network

A data communication network can be considered to consist functionally of transmission links, switches, and protocols. The former two items are hardware oriented while the latter is procedural.

Transmission links transport electrical signals between desired points: a network consists of a collection of such links. If the interconnection pattern is alterable, the altering agents are called switches. Protocols provide procedures for: (1) resolving contention for links, (2) regulating the flow of traffic on links, (3) managing errors and faults, (4) providing message addressing and priority information to switches, and (5) passing of control information between switches.

Transmission links and switches are often highly multiplexed so that they can concurrently serve many users. Tens to hundreds of users may share a common resource. The current technology for transmission uses a frequency, time, space, information (or some combination of these) techniques to effect signal separation while sharing. For switching, time and space sharing techniques are used.

a. Transmission Links

Electromagnetic transmission processes may be categorized as those involving signals carried by conductors (for example, pairs of wires, coaxial cables) and those involving radio. Radio transmission embraces terrestrial transmitters and receivers that are either earth-bound or airborne; whereas satellite radio communication involves a satellite or the earth.

Data transmission requires modulation of some characteristic of the transmitted energy. Modulation can be performed on the energy's amplitude (AM), frequency (FM), phase (PM), or some combination of these. Considerations of power, noise, bandwidth, and interference dictate the use of the modulation technique.

Each modulation technique permits many levels of gradation to be transmitted. When many levels are transmitted, the transmission is referred to as analog, because the many-level technique is often used when the transmitted signals are analogous representations of the signals causing the modulation. Although noise is always present in electronic signals due to various natural phenomena (man-made electrical noise may also be present); analog signals are particularly susceptible to the effects of these noises.

Binary signals contrast with analog, in that only two levels of gradation need to be transmitted and received. With only two levels to sense, the detection process becomes strongly immune to the influence of noise. Further, with binary signals, simple digital techniques can be employed in the transmission hardware (and switching). Finally, digital transmission is compatible with the digital signals used by

computer systems and terminals. The net effect is that, relative to analog transmission, digital transmission affords lower cost of equipment, installation, and maintenance; ability to use poorer quality circuits; increased use of the available spectrum, and improved noise rejection.

While digital transmission is directly compatible with computer and terminal signals, such is not the case with inherently analog signals, such as voice. As a result special hardware is needed, for telephone applications, to provide a digital to analog (D/A), and an analog to digital (A/D) conversion. A tradeoff exists between (1) the cost of the conversion equipment, (2) the quality of the transformation, and (3) the data rate of the digital information stream. (The smaller the data rate the greater the number of voice signals that can be carried by a given digital transmission link.)

The data rates for voice signals can range from about 40 Kbps (kilo bits per second) to about 2.4 Kbps. By way of comparison an ADPS terminal can be supported by data rates from about 2.4 Kbps to 75 bps; thus data tends to occupy less of a transmission link than voice. Once digitized, both voice and data can be freely intermixed on transmission links.

b. Switches

Communication switches primarily exist to provide economies of transmission and of terminals. Switching reduces the number of resources that are dedicated to specific transmission links by introducing a means of centralizing and sharing transmission link resources. Large reductions arise with large network communities. The cost of the switch is offset by the circuit and terminal savings. With a large enough community more than one switch may be needed to shorten the lengths of the circuits between switches and terminals. If all locations are to be able to communicate with all others, then the switches themselves must be interconnected by communication links. In fact, the switches themselves can form a community that justifies its own set of switches.

The introduction of switching presents the problem of addressing: (1) each potential receiver of information needs to be identified so that things can be directed to it by the switches, (2) input sources must be able to indicate to the switches the identity of the intended data, (3) priority may need to be indicated to the switch, (4) provisions are needed to cope with unavailable receivers, congestion, transmission errors, or other conditions that inhibit the delivery of error-free information to the intended addresses.

Three different switching techniques are used: circuit switching, store and forward switching, and packet switching. Circuit switching is the common method of telephone switching, and provides a communication channel between the calling and the called nodes. This channel can, in fact, be a serial string of transmission links selected by the switches and dedicated solely to the two nodes for the duration of the call. Upon call completion, the various links are released and returned to a pool of links available for use by other calls. With circuit switching, the end-to-end channel is dedicated to the call even during periods when no data is being transmitted. The end-to-end channel cannot be established with circuit switching until all links within the channel are simultaneously available. Once established, however, transmitters and receivers at opposite ends are in direct and immediate communication.

Store and forward (S/F) switching results in the switch receiving and storing an entire message, forwarding that message at some later time when transmission links or destination terminals become available. S/F switching decouples the sender from the designated receiver(s). Since delivery of a message does not require all links and the designated receiver to be simultaneously available, S/F switching can tolerate (better than circuit switching can) busy terminals and links. This is particularly true when the sender has a multiaddress message (that is, one for many terminals).

S/F switching has some disadvantages. If messages are long, S/F switching can introduce long delivery delays. Also, the sender may not know for certain that a message has been delivered, for in S/F

switching the network assumes responsibility for delivery, but may fail to effect delivery. This form of switching is most often used with teletypewriter message traffic.

Packet switching is the third technique. It is based on digital transmission and switching technology and is related to S/F switching. The packet is the message, and a packet is usually limited to a maximum size (on the order of 1000 bits). All the bits of a packet are part of the same data transfer from a given source to a given destination. The packet is a convenient unit for the digital switches and digital links to handle. The packet can be easily stored within the main memory of the computer which is the packet switch. The packet also provides a good unit upon which the digital link can provide error detection.

When the "basic" message (such as the contents of a data file) exceeds the size of a packet, that message is subdivided into multiple packets by the telecommunication network at its point of entry into the network. Conversely, the "basic" message is reconstructed by the network at the message's destination. Elsewhere in the network only packets are processed. Some forms of "basic" message are "bursty" by nature and lend themselves to packets. Input and output of terminals are such forms.

The complex, high speed logic of the computer switch permits dynamic high speed interleaving of packets on a link, and the dynamic routing of packets through a network. This tends to improve link utilization, minimize transit delay, and provide for highly adaptable operation even in the face of network failures or congestion. Voice traffic is also "bursty" considering the many periods of silence even when a person is speaking, so that digitized voice is a candidate for packet switching, and may be so switched in the future. Such a circumstance would result in a single unified network for transmitting and switching data and voice.

c. Traffic

Traffic refers to the flow of messages through a network of transmission links, switches, and among the set of terminals that the

network connects. Traffic is characterized in terms of a source-destination matrix, with each element of the matrix consisting of the following traffic attributes: (1) rate of message origination, (2) size of message in bits (for digital traffic), and (3) acceptable delivery delay. Often these attributes are stated in statistical terms such as averages and variances.

In some cases a terminal may send or receive traffic that is a mixture of very different types, such as binary data and digitized voice. In such instances the different traffic types are separately recognized in the traffic matrix rather than subjected to an attempt to produce a meaningless aggregate statistical description.

In the analysis of traffic, it is becoming increasingly difficult to identify an entity that is the "message." Consider telephone traffic with respect to circuit switching and with respect to packet switching. In the case of circuit switching, the message involves the entire conversation of a single "call." Thus the message origination rate is measured by the rate at which calls are placed, and the message size is measured by the time both parties are "off-hook" for the given call.

For packet switching the message would be the packet, and for speech many packets a second would be generated as bursts of speech are digitized and formed into packets. The packet size is the message size, and it is dependent upon the nature of the speech bursts and the digitizing process. Thus, for the same telephone call, the packet-switching message origination rate would be two or more magnitudes greater than the message rate for the identical circuits switched call.

Three aspects of communications traffic dominate its impact upon the design and performance of the supporting telecommunication network:

- Connectivity--This describes the capability of the network to pass any messages at all between given pairs of network nodes. For a traffic matrix to be satisfied, at least every source-destination pair with a nonzero message origination rate must be capable of being in communication via the network.

- Link capacity--Traffic intensity is the product of message origination rate and message size (in equivalent time), and it is measured in the dimension unit of the Erlang--each link having an equivalent Erlang capacity. For reasons of queuing (delay in service due to congestion) links are often loaded, on the average, at less than full capacity; the 50% to 70% range is not unusual. If the intensity of the offered traffic exceeds the links capacity, then an infinite queue and a corresponding infinite delay can theoretically arise.
- Switching capacity--The primary factor affecting switches is the rate of message origination, for most switch designs are throughput limited by the controller. The controller, itself, is rated in terms of the number of messages per second that it can process. In the case of a computer-based controller this rate may be many tens to a few hundreds of messages per second. To a lesser extent message length affects switching due to the message storage aspects required of such switches.

d. Network Topology

Network topology refers to the interconnection pattern among switches, and between switches and terminals. This pattern tends to be dictated by the nature of the traffic matrix. Thus, if the matrix reflects vertical message flow within a pyramidal organization, the network can be expected to functionally resemble a pyramid.

The topology is also strongly affected by the technology of transmission links. Typically, economies of scale make it desirable to provide large capacity links for use on long hauls. Satellite circuits, cables, and some microwave systems are examples of this. To realize these economies it is necessary to bring traffic to such links and to lead it away. This concentration function can be performed by switching.

Finally topology is affected by survivability considerations. By providing additional transmission links and switches, a network can be designed to provide more than one patch between a chosen set of point-pairs in a network. The logic of the switch controllers can provide for automatic alternate routing of messages around unavailable network elements. Recovery, upon operational restoration, can also be provided. Use of alternate routes can also automatically be invoked by the switches

in case of abnormally large traffic input, so as to make best use of all available network resources to cope with overloads.

It should not be inferred that telecommunications networks need be geographically fixed. Current and future technology permits (1) rapid addition or deletion of switches and transmission links, (2) movement of switches, and (3) movement of terminals. Searching and adaptive algorithms can be used by the switch control to accommodate such network changes. Terminal movement can be such that a mobile unit, using a radio link to a switch, should be able to move at will within the network, and the switch control will automatically adapt so that the switch best able to serve that mobile terminal will do so.

Such adaptation has an impact upon the network addressing scheme. Such schemes and adaptation processes should also permit a user (rather than a terminal) to be addressed. As the user moves about in an area, the network could be made to automatically address that person via a terminal selected by the user.

4. Marine Corps Long Range Plans for Communications

The Marine Corps long-term telecommunications requirements, for both voice and data, are to be satisfied by LFICS (Landing Force Integrated Communications System).[31] A prime mission of LFICS is to support MTACCS (Marine Tactical Command and Control System). Many key elements of LFICS are to be provided by the TRI-TAC development.

Current LFICS plans call for a major transition to occur in Marine Corps communications during the period FY 1985-1990. The transition affects terminals (both voice and data), transmission links, multiplexers, and switches. This period will see (1) the phasing in of digital elements and the phasing out of analog elements, (2) the phasing in of wide band circuit switches and automatic store and forward switches and the phasing out of manual store and forward switches, and (3) the phasing in of encryption devices.

While the long term provides for essentially all digital networks, the 1980s will continue to see the use of analog radio equipment modified to also accommodate digital signals.

a. Transmission

The primary orientation of LFICS is toward voice communication, but data communication is to be supported and accommodated even in these early planning stages. The network provides for analog to digital conversions and vice versa. Digitized voice, in the long term will represent a bit stream of 16 Kbps (kilo bit per second). For this reason the basic transmission channel is to be 16 Kbps. By means of a family of digital multiplexers, many of these channels may be combined into very high speed bit streams at data rates of 288 Kbps, 576 Kbps, 1152 Kbps, and 2304 Kbps.

While wire transmission is sometimes used, the emphasis is upon radio links. Five classes of radio equipment are envisioned to cover the following portions of the radio spectrum:

- 2 to 30 MHz
- 30 to 80 MHz
- 225 to 400 MHz
- 4.4 to 5.0 GHz
- 7.9 to 8.4 GHz

The equipment used in these frequency ranges emphasizes mobility and portability.

The 30 to 80 MHz, and 225 to 400 MHz ranges are primarily used for line of sight, short range (e.g., 30 miles or less) point to point or broadcast links. Channel spacings are 25 KHz or 50 KHz, providing thousands of channels. Spread spectrums and frequency-hopping techniques will be used in some equipment for reasons of electronic countermeasures, antijamming, and added transmission security. Some equipment in the 225 to 400 MHz range may also be used for satellite communications, even with a man-pack.

The 2 to 30 MHz range is primarily used for long haul, terrestrial (that is, shortwave) links. Bandwidth limitations in this part of the spectrum preclude the use of 16 Kbps channels. Instead narrowband (for example, 3 KHz) analog techniques are used for voice security and 2.4 Kbps data streams. Special converters and multiplexers are needed at the interface between these narrowband analog, and high speed digital systems.

Satellite links use the 7.9 to 8.4 GHz bands: Troposcatter links use the 4.4 to 5.0 GHz band.

Associated with the transmission elements are digital multiplexers. A family of multiplexers is planned. Used in various combinations, basic 16 Kbps channels can be multiplexed to form data streams as fast as 2304 Kbps.

b. Terminals

A variety of digital voice, data and facsimile terminals are planned. The digital voice terminals involve analog to digital (A/D) conversions and vice versa. A standard signal processing technique will be used--CVSD (continuously variable slope delta). There are to be two types of digital telephones--the DSVT (digital secure voice terminal) which is secure, and the DNVT (digital nonsecure voice terminal). Complementing these two digital telephones will still be an analog telephone. A/D and D/A conversions at the interfaces between analog and digital elements will permit intercommunication between both terminal types.

A large set of data terminals are planned. In their various modular forms and types they will encompass printers, teletypewriters, CRTs, data storage devices, and small processors. Among the functions these terminals may perform are operator prompting during message creation and generation of "canned" messages.

c. Switches

Switch capabilities to be accrued can be classified as large automatic circuit and message switching for higher headquarters (such as

MAF, Division, and Wing) and those to be acquired by units below the Division/Wing level. The large circuit switch can switch both voice and data through the use of a data adapter. The smaller unit level circuit and message switching will provide telephone and data/narrative traffic respectively. Limited data can be accommodated by this small circuit switch with the employment of a data adapter.

Circuit switches will use predominantly time division technology. A limited analog capability (less than 10%) will be included to facilitate the transition to the all digital communications system of the future.

The wideband switching capability eliminates the need for analog to digital conversions (and vice versa) for voice signals to transit the circuit switches. Such direct switching improves voice quality, reduces cost, and improves reliability.

Included with the switches may be A/D converters and crypto equipment to permit the interconnection of analog and digital voice terminals via the switch. The message switches will operate at data rates up to 16 Kbps.

5. Potential ADPS Requirements and the Marine Corps Long Range Plans for Communications

In this section, a broad look is taken at potential ADPS communication requirements, and these are compared with the Marine Corps communication plans for the 1980-90 period.

Data transfers among elements of the ADPS may be characterized as batch or interactive. Batch transfers are primarily files or records exchanged between computer systems or transferred from a system to an output device such as a printer. The size of the total transfer may be hundreds to 250 K characters. While speed of transfer is important, response times in excess of 10 seconds may be acceptable.

Interactive transfers involve human operators communicating with a computer via a terminal such as a CRT with a keyboard, or a teletypewriter. Time is of the essence in this mode of operation such that a

computer response must be provided within 5 seconds, or so, including all transmission and switching delays. The nature and frequency of required computer response is dependent upon the nature of the application and the manner of its implementation.

At one extreme each operator keystroke requires a computer response. At another extreme the operator may make several hundred keystrokes before a response is needed. In between these extremes, a few tens of characters (for example, a line of text) may be entered before computer action is required.

In most of these instances the volume of transfer from the interactive terminal to the computer may be the order of 10% of the transfer from the computer to the terminal. Also, operators tend to work in spurts so that there may be periods of several tens of seconds when there are no communication exchanges between a terminal and its computer.

The digital network envisioned for the Marine Corps provides the potential to satisfy most data transmission needs for a variety of alternative ADPS network configurations. This notion is based on the large capacity represented by 16 Kbps "voice" channel. If the ADPS is topologically stable, that is, if interconnections among the ADPS elements remain fixed even though the elements may be mobile, then dedicated communication channels could be used.

If, however, communication resources are scarce, then dedication of channels to ADPS may be impractical. Nondedicated channels could be used, but it must be recognized that only circuit switching or slow message switching would be available. These forms of switching could well satisfy the needs for such communications.

In the case of interactive terminal traffic, however, message switching definitely would not provide adequate response time. Circuit switching may or may not be suitable. With interactive traffic the circuit switch could be used in either of two ways: (1) the switch could be used to set up a connection between a terminal and its host computer for the duration of a transaction or a sequence of transactions, (2) the switch

could be used to set up a connection each time a response is needed from the lost computer and to effect a disconnect after the host responds.

The first example could satisfy terminal response time requirements without an undue burden on the circuit switch, but it could effectively result in circuit dedication, because each "call" might be set up for tens of minutes.

The second example permits channel sharing between terminals and other users but it can degrade terminal response time (because of switching delays) and it can heavily burden the switch with a high rate of "calls."

This problem of switching requires further attention. Packet switching, when ultimately deployed, may provide the solution for a smooth blending of computer and other traffic. Packet radio, in particular, should be examined. Due to the long lead times involved (potential deployment could be in the very late 1980s), the ADPS may need to adopt both an interim and long-term design.

REFERENCES

1. "Support of Air Force Automatic Data Processing Requirements Through the 1980's (SADPR-85), Volume III. Technology," Report ESD-TR-74-192, Electronics Systems Division, Hanscom AFB, Massachusetts (June 1974), AD-783 769.

2. Proceedings of the IEEE, Special Issue on Microprocessor Technology & Applications, The Institute of Electrical and Electronics Engineers, Vol. 64, No. 6 (June 1976).

3. "Is the General-Purpose Computer Dying?" Auerbach Reporter, Computer Technology Edition, Auerbach Publishers Inc., Philadelphia, Pennsylvania (November 1974).

4. "Microprocessors and Microcomputers," Auerbach Reporter, Computer Technology Edition, Auerbach Publishers Inc., Philadelphia, Pennsylvania (July 1974).

5. "MTACCS Integrated Logistics Support--Task III," Final Report, FR 75-16-337, Ground Systems Group, Hughes Aircraft Company, Fullerton, California, (20 June 1975).

6. Proceedings of the IEEE, Special Issue on Large Capacity Digital Storage Systems, The Institute of Electrical and Electronics Engineers, Vol. 63, No. 8 (August 1975).

7. Ypma, J.E., "Bubble Domain Memory Systems," AFIPS Conference Proceedings, Volume 44, 1975 National Computer Conference, AFIPS Press, Montvale, New Jersey (1975).

8. "Data Management Device Requirements Study Final Report," Technical Report TR-74-1582-D6, Informatics, Inc., Alexandria, Virginia (30 June 1974).

9. "The Dream Data Entry Machine," Auerbach Reporter, Computer Technology Edition, Auerbach Publishers Inc., Philadelphia, Pennsylvania (August 1974).

10. "The Computer Terminal Salad Bowl, Part One: The Changing Environment," Auerbach Reporter, Computer Technology Edition, Auerbach Publishers Inc., Philadelphia, Pennsylvania (November 1975).

PRECEDING PAGE BLANK-NOT FILMED

11. Proceedings of the IEEE, Special Issue on Interactive Computer Systems, The Institute of Electrical and Electronics Engineers, Vol. 63, No. 6 (June 1975).

12. Date, C.J., An Introduction to Data Base Systems (Addison-Wesley, Reading, Mass., 1975).

13. Martin, J., Computer Data-Base Organization (Prentice-Hall, Inc., Englewood Cliffs, N.J., 1975).

14. "Data Management," Datapro Research Corporation, Delran, N.J., D30-100-001--D30-200-007 (May 1976).

15. ACM Computing Surveys, Special Issue on Data Base Management Systems, Association for Computing Machinery, New York, Vol. 8, No. 1 (March 1976).

16. "The Data Dictionary/Directory Function," EDP Analyzer, R.J. Canning, Publisher, Vista, Calif., Vol. 12, No. 11 (November 1974).

17. "Auerbach Computer Technology Reports," Auerbach Publishers, Inc., Philadelphia, 620.0000.200--620.2526.040, (1975, 1976).

18. "Distributed Data Systems," EDP Analyzer, R.J. Canning, Publisher, Vista, Calif., Vol. 14, No. 6 (June 1976).

19. "Distributed Systems," EDP Analyzer, R.J. Canning, Publisher, Vista Calif., Vol. 14, No. 10 (October 1976).

20. "Codasyl Type DBMS," EDP Analyzer, R.J. Canning, Publisher, Vista, Calif., Vol. 12, No. 10 (October 1974).

21. Curtice, R.M., "Some Tools for Data Base Development," Datamation, Vol. 22, No. 4 (April 1976).

22. DeRose, B.C., "Defense System Software Management Plan," DoD OSD I&L (March 1976) (AD/A-022 558).

23. Asch, A., "DoD Weapon Systems Software Acquisition and Management Study," Vol. 1, Metre Corporation, Bedford, Mass. (May 1975).

24. McIntosh, C.S., "Analysis of Major Computer Operating Systems," The Comtre Corp. (August 1970). (AD 715 919).

25. "The Design and Evaluation of Information Systems," Proceedings of the Defense Research Seminar, Athens, Greece (April [illegible]). (AD-B001 089).

26. Gerken, B.L., "An Approach to the Evaluation and Selection of Data Management Systems," Metre Corporation, Bedford, Mass. [illegible] (MTR-2285).

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AD A049785

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DDC

27. Boehm, B.W., et al., "Characteristics of Software Quality," Document No. 25201-6001-RU-00, TRW Systems (December 1973).

28. Keirstead, R.E., "Feasibility of Software Certification Study," SRI Workshop Proceedings," Stanford Research Institute, Menlo Park, Calif. (December 1973). (PB 245 213/AS).

29. "The Upgrading of Computer Operators," EDP Analyzer, R.J. Canning, Publisher, Vista, Calif., Vol. 12, No. 9 (September 1974).

30. "Data Base Administration--A Management Overview," Auerbach Publishers, Inc., Philadelphia, 22-01-03 (1976).

31. "Landing Force Integrated Communications System Architecture 1976-1990," Marine Corps Development and Education Command (April 1976).

32. Pike, T.N., Jr., and R.P. Blane, "Computer Networking Technology - A State of the Art Review," IEEE Computer, Vol. 6, pp 12-19 (August 1973).

33. Andrews, M.C and F.P. Corr, "A User's View of Integrated Digital Communications Facilities," Proceedings 1972 International Zurich Seminar on Integrated Systems for Speech, Video and Data Communications, pp E1 (1) - E1 (5) (15-17 March 1977).

34. Chou, W., "Computer Communication Networks - The Parts Make Up the Whole," Proceedings of AFIPS Nat. Comp. Conf., Vol. 44, pp 119-128 (19-22 May 1975).